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DILLON RESERVOIR - BLUE RIVER STUDY

COLORADO, JUNE, JULY, AUGUST - 1973

ENVIRONMENTAL PROTECTION AGENCY

JANUARY 1974

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The Environmental Protection Agency, Region VIII conducted a sampling program of the Dillon Reservoir - Blue River System, Colorado over three-day sampling periods during the months of June, July and August, 1973. A laboratory study of the algal growth potential of the reservoir was included in the study to determine the probable consequences of increased nutrient and molybdenum levels in Dillon Reservoir relating to nuisance algal growths. The report discusses the nutrient levels in the reservoir during the study period, the sources and amounts of nutrient and organic loadings of the major tributaries and wastewater treatment facilities discharging to the reservoir, and the findings of the laboratory algal growth potential study.

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INTRODUCTION

The Dillon Reservoir area has developed into one of the fastest growing areas in Colorado. The development of recreational facilities in the area has resulted in a building boom of private homes, apartments, condominiums and businesses. Over the past few years more than a dozen wastewater treatment facilities have been constructed in addition to the numerous individual type septic tank systems to serve three ski areas and the growing communities of Dillon, Breckenridge and Frisco. The new Copper Mountain ski area and community is presently under development where a projected population of 25,000 will affect the reservoir.

This increasing population growth in the Dillon Reservoir area has prompted concern for the future of the waters in the reservoir. The addition of nutrients to the reservoir from the surrounding areas may cause deterioration of its trophic structure, creating the possibility of nuisance algal blooms and other problems such as odor and discoloration associated with eutrophication.

An investigation of the Dillon Reservoir - Blue River area was conducted to assess the impact of nutrient addition to the reservoir. The investigation was conducted over three-day sampling periods during each of the three summer months: June 27-29, July 9-11, and August 13-15. In the reservoir, samples were collected from the epilimnion and hypolimnion at each sampling station. The study concentrated on the following objectives:

1. To determine the existing nutrient levels in Dillon Reservoir.

2. To determine the organic and nutrient loadings from the major tributaries feeding the reservoir.

3. To determine the organic and nutrient loading from municipal wastewater treatment facilities discharging into the reservoir and its tributaries.

4. To determine the probable consequences of increased nutrient levels in the reservoir as regards nuisance algal growths.

The investigation as related to item (4) included a laboratory study of the algal growth potential of the reservoir. Since high levels of molybdenum occur in Dillon Reservoir as a result of mining activities in the Ten Mile Creek watershed, additional algal assays were conducted to determine the effect of molybdenum on algal growth in reservoir water.

DESCRIPTION OF STUDY AREA

Dillon Reservoir, located west of the Continental Divide approximately 112.7 kilometers (70 miles) west of Denver, Colorado, at an elevation of 2750.19 meters (9,017 feet), behind an earth-filled dam, has a surface area of 12.03 square kilometers (2,970 acres) and storage capacity of 309,842,629 cubic meters (254,036 acre-feet). The reservoir, a major Colorado water project, was completed in 1963 to serve as part of the Denver, Colorado water supply.

The reservoir receives water from three major tributaries; the Blue River, the Snake River, and Ten Mile Creek. Water discharged from the dam enters the Blue River. Approximately 218,322,720 cubic meters (179,000 acre-feet) per year is diverted from the reservoir through the Roberts Tunnel, a 37.03 kilometer (23 mile) long, concrete lined, 3.05 meters (10 foot) diameter tunnel under the Continental Divide, for use by the City of Denver.

The geological history of the Dillon area, like that of the Denver area indicates that the areas were once old water-deposited areas from what is now the Gulf of Mexico until the Rocky Mountains were lifted to form the Continental Divide.

SURVEY METHODS

To determine existing water quality and biological conditions in Dillon Reservoir and its tributaries, sampling stations were established at (1) six cross-sections in the reservoir (Figure 1); (2) six locations on the three major tributaries feeding the reservoir (the Blue River, Snake River, and Ten Mile Creek); (3) one location immediately downstream from the reservoir outlet; and (4) the effluents of six wastewater treatment facilities discharging to Dillon Reservoir or its tributaries.

All water quality samples collected were "grab" type samples. At each station, samplers made field determinations for temperature, pH, and dissolved oxygen and collected additional sample for laboratory determinations. The laboratory determinations included 5-day biochemical oxygen demand, total coliform, fecal coliform, suspended solids for tributaries and effluents only; and molybdenum, iron, nutrients (nitrogen and phosphorus series) for all locations.

At each of the reservoir cross-sections, temperature and dissolved oxygen vs depth profiles were made. A direct reading thermistor - thermometer equipped with a 62 meter (200 ft) cable was used to determine subsurface temperatures. Dissolved oxygen concentrations present in water samples collected at various depths, were determined with either a D.O. probe or wet chemical methods. A submarine photometer was used to determine the depth of light penetration at the mid-point of each transect on 6/29, 7/9 and 7/10, 1973. Phytoplankton samples were collected at the midpoint of each transect during the 7/10/73 survey. Sampling depths were determined according to the depth of the euphotic zone delineated by the one percent level of light transmission.

In addition, flow measurements were also made in conjunction with tributary and effluent sampling at each wastewater treatment facility.

The methodology for the laboratory study of algal growth potential in the reservoir will be discussed in detail in a separate section.

A detailed description of station locations and results of all analyses appear in Appendix A.

Figure 1. Sampling station location map.

RESULTS OF STUDY

I. Existing Nutrient Levels and Productivity in Dillon Reservoir

It is recognized that the mechanics of eutrophication are complex, however it is also recognized that both nitrogen and phosphorus are important nutrients contributing to the eutrophication of a lake or reservoir. Studies by Sawyer (1947) have led to the conclusion that concentrations of nitrogen in excess of 0.30 mg/l as N and phosphorus in excess of 0.01 mg/l as P at the start of the active growing season could be expected to produce nuisance algal blooms.* Under certain conditions, there may be waters where higher concentrations of nutrients (nitrogen and phosphorus) than that considered acceptable, do not produce eutrophication. Likewise, there are waters with concentrations of nutrients lower than that considered as maximum, where populations of nuisance organisms thrive. Because of this, it is recommended that any standards for nutrients be established on a case-by-case basis and that nutrient budgets and algal assays be used in establishing any nutrient standards. It is further recommended that the naturally occurring ratios and amounts of nitrogen to phosphorus not be allowed to be radically altered through the addition of materials.

As a guideline, it is recommended that the concentrations of total phosphorus not be allowed to increase to levels exceeding 0.1 mg/l as P in flowing waters or 0.05 mg/l in lakes or reservoirs or streams entering lakes or reservoirs.** Currently proposed Colorado standards for Class B 1 waters, the present classification for the Blue River - Dillon Reservoir system, call for the total phosphorus for the waters not to exceed a concentration of 0.05 mg/l (Table 1). The results of all data collected during the June through August study period indicate that the 0.05 mg/l total phosphorus criteria was exceeded at only two locations in Dillon Reservoir, the outlets of the Blue River Arm and Dillon Bay, Sections B & G respectively (Table 2 and Appendix Tables A-2 through 22). Although numerical guidelines for nitrogen concentrations are not established, the concentrations of nitrogen in Dillon Reservoir are not considered to be excessive (Table 3 and Appendix Tables A-2 through 22).

* Mackenthun, K.M. 1969. The Practice of Water Pollution Biology. U.S. Dept. of the Interior, Fed. Water Poll. Control Administration, 281 pp.

** Environmental Protection Agency. 1973. Proposed Criteria For Water Quality-Volume I. EPA. Washington, D.C., 425 pp.

TABLE 1

COLORADO WATER QUALITY STANDARDS SUMMARY

(Proposed)

STANDARD	CLASS B_1
Settleable Solids	Essentially Free
Floating Solids	Essentially Free
Taste, Odor, Color	Essentially Free
Toxic Materials	Essentially Free
Oil and Grease	Maximum - 10 mg/1
Radioactive Material	Drinking Water Standards
Salinity	At or below present levels
Fecal Coliform Bacteria	Geometric Mean of<1000/100 ml from five samples in 30-day per
Turbidity	No increase of more than 10 J.T.U.
Dissolved Oxygen	6 mg/1 minimum
Total Dissolved Gas Pressure	Maximum of 110% of atmospheric pressure
pH	6.0 - 9.0
Temperature	Maximum 68° F. Maximum Change 2° F
Phosphorus as P	Streams-max. 100 ug/1 Lakes-max. 50 ug/1
Fecal Streptococcus	- - - - - - - - - -

TABLE 2

Total phosporus in Dillon Reservoir
Range of Values

		Quarter Points		
		1	2	3
A	S	0.005	0.009 - 0.018	0.009
	M	0.013	0.012 - 0.016	0.007
	B	0.014	0.011 - 0.015	0.007
B	S	0.007	0.010 - 0.017	0.010
	M	0.022	0.010 - 0.021	0.011
	B	0.180	0.010 - 0.015	0.012
C	S	0.018	0.012 - 0.031	0.013
	M	0.014	0.014 - 0.024	0.015
	B	0.010	0.014 - 0.029	0.023
D	S	0.008	0.006 - 0.015	0.008
	M	0.008	0.005 - 0.017	0.008
	B	0.006	0.005 - 0.017	0.009
E	S	0.010	0.007 - 0.012	0.007
	M	0.009	0.006 - 0.017	0.008
	B	0.005	0.005 - 0.011	0.005
F	S	0.015	0.011 - 0.013	0.011
	M	0.010	0.008 - 0.020	0.009
	B	0.007	0.008 - 0.013	-
G	S	0.023	0.011 - 0.092	0.144
	M	0.136	0.011 - 0.016	0.012
	B	0.008	0.010 - 0.422	0.013

S = surface
M = mid depth
B = bottom

All concentrations in mg/l as P

TABLE 3

Total Kjeldahl Nitrogen in Dillon Reservoir
Range of Values

		Quarter Points		
		1	2	3
A	S	0.20	0.20 - 0.30	0.20
	M	0.20	0.20	0.20
	B	0.20	0.20	0.20
B	S	0.30	0.20 - 0.50	0.30
	M	0.30	0.20	0.20
	B	0.30	0.20	0.10
C	S	0.30	0.20	0.20
	M	0.30	0.20	0.20
	B	0.20	0.20 - 0.30	0.20
D	S	0.20	0.10 - 0.30	0.30
	M	0.20	0.20 - 0.30	0.30
	B	0.20	0.10 - 0.30	0.20
E	S	0.40	0.20	0.30
	M	0.10	0.10 - 0.20	0.20
	B	0.10	0.10	0.10
F	S	0.20	0.20 - 0.30	0.30
	M	0.20	0.10 - 0.30	0.20
	B	0.20	0.10 - 0.20	-
G	S	0.20	0.10	0.20
	M	0.20	0.10 - 0.20	0.30
	B	0.20	0.10 - 0.20	0.20

S = surface
M = mid depth
B = bottom

All concentrations in mg/l (TNN-N)

Dillon Reservoir is a dimictic body of water with a spring and fall overturn and a summer thermocline. During each sampling period, temperature profiles were measured and plotted in order to determine the presence and depth of the thermocline (Figure 2 to 5). When present a thermocline limits nutrient exchange between surface and bottom waters and thus acts as one limit to phytoplankton production in the reservoir. The temperature profiles of Dillon Reservoir indicated a well defined thermocline approximately 10 meters (30.4 ft.) deep at all stations in August. During June and July, temperatures in the reservoir changed gradually from top to bottom and except for Station B, a well defined zone of temperature decrease was not measured. An exchange of nutrients from bottom to surface waters caused by wind action could occur from the period of ice cover break-up to August, a time span of four to five months.

The depth of light penetration in a water body limits the volume of water within which photosynthesis, necessary for primary productivity, can occur. Since photosynthetic activity is restricted when the available light is less than one percent of that light at the surface, the zone of water from surface to the one percent level is the layer within which primary production (phytoplankton reproduction and growth) can occur and is known as the euphotic zone.

In Dillon Reservoir, the euphotic zone was measured at 20 to 25 feet (6.1 to 7.6 meters) in June and 24 to 29.5 feet (7.3 to 9.0 meters) in July (Table 4). With the thermocline deeper than the euphotic zone, essentially all the water from the surface down to a mean depth of 21.6 feet (6.7 meters) is available for plankton production, limited by the amount of nutrients trapped in the upper layers after thermocline formation. This layer has been calculated to be approximately 25 percent of the total lake volume.

During the July survey, the phytoplankton community in Dillon Reservoir was typical of a northern latitude cold water lake with diatoms predominant. A pennate diatom, Synedra sp. was the dominant genera (Table 5). Green algae and miscellaneous algae represented an insignificant amount of the plankton population collected during the July sampling period. The largest numbers of phytoplankton were collected at the eight to nine foot (2.5 to 2.8 meters) level indicating a probable preference for less light than that available at the surface. An examination of the nutrient concentrations (Appendix Tables A-2 through 22) indicates no significant difference in concentrations, at depths samples, that would produce increased phytoplankton numbers at the 2.5 to 2.8 meter level.

Phytoplankton numbers (Table 5) indicate that the oligotrophic status of Dillon Reservoir may be changing to a more enriched water body. Total phytoplankton numbers ranged from 1348 cells per milliliter (ml.) at Station E to 3328 cells per ml. at Station B. Applying the general definition of an algae bloom, proposed by

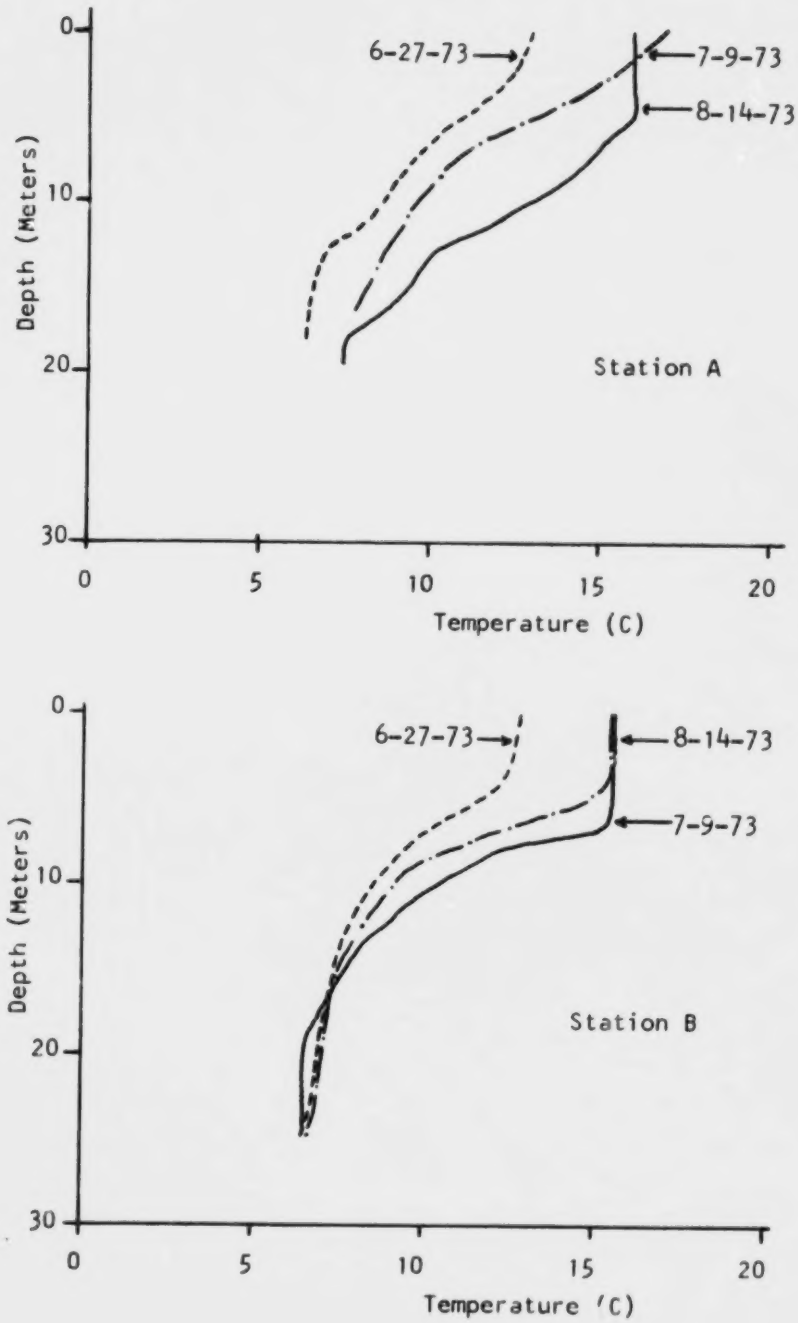
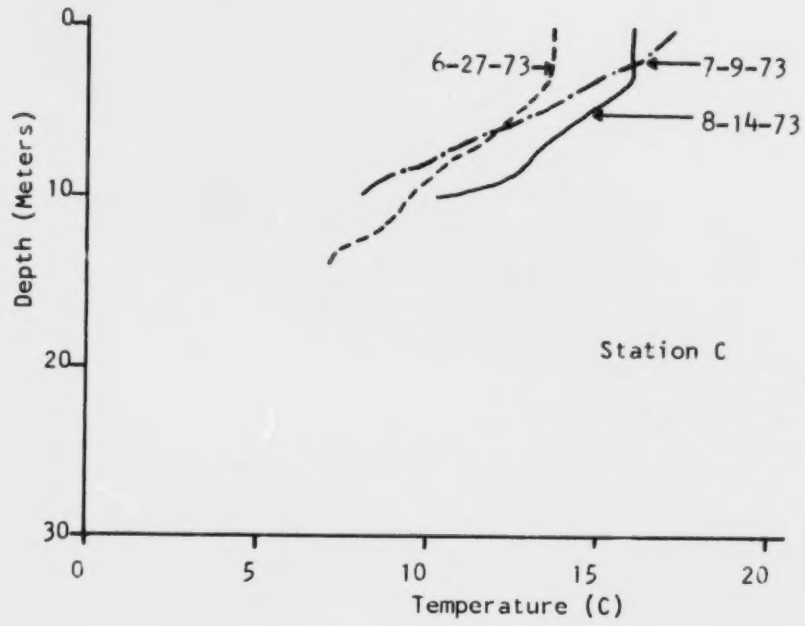


Figure 2 Temperature profiles, Dillon Reservoir, Sampling Stations A and B.



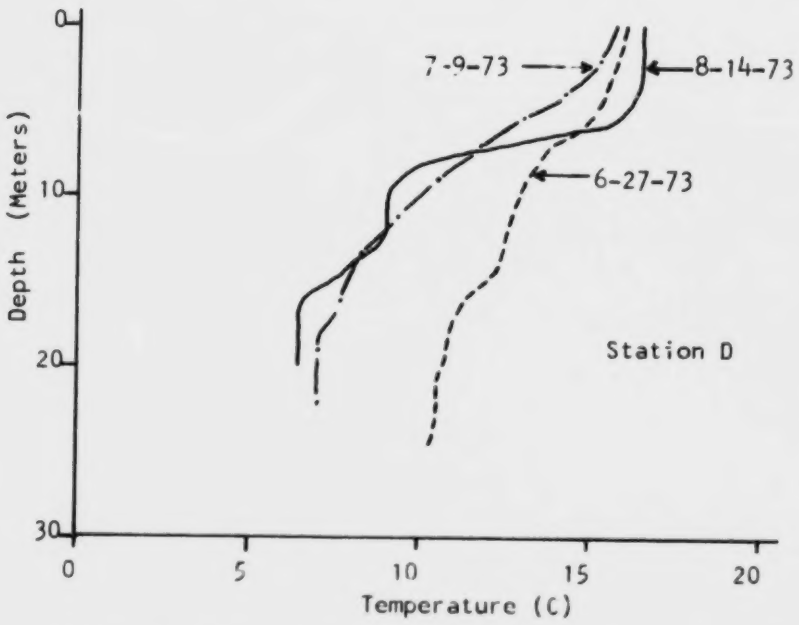
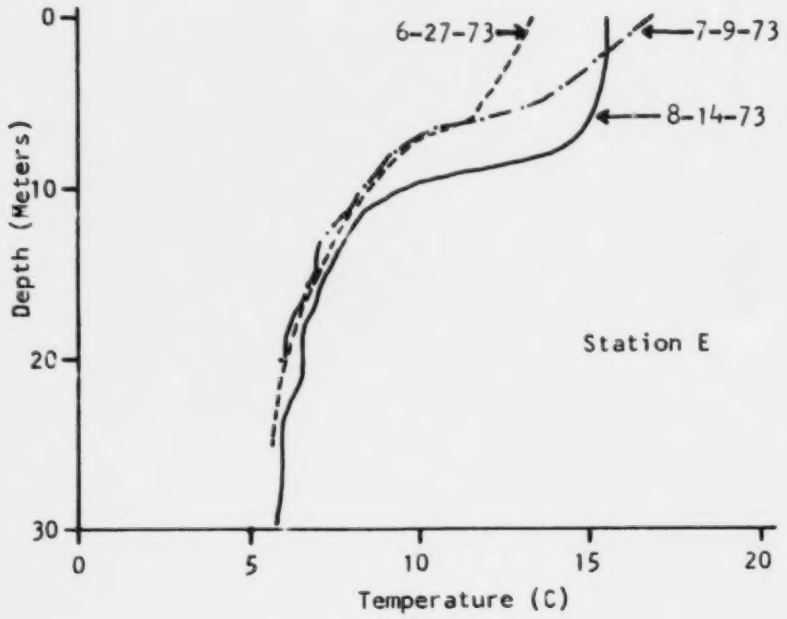


Figure 3 Temperature profiles, Dillon Reservoir, Sampling Stations C and D.



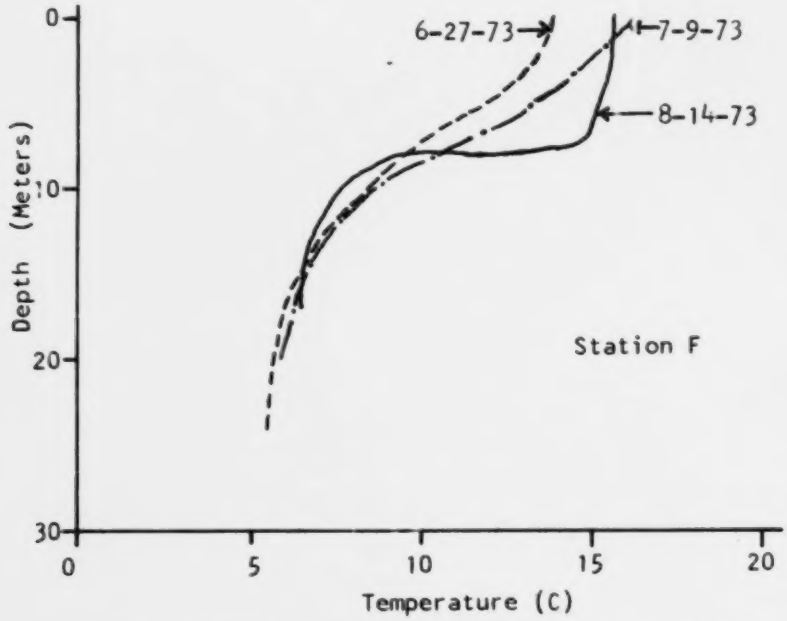


Figure 4 Temperature profiles, Dillon Reservoir, Sampling Stations Eand F.

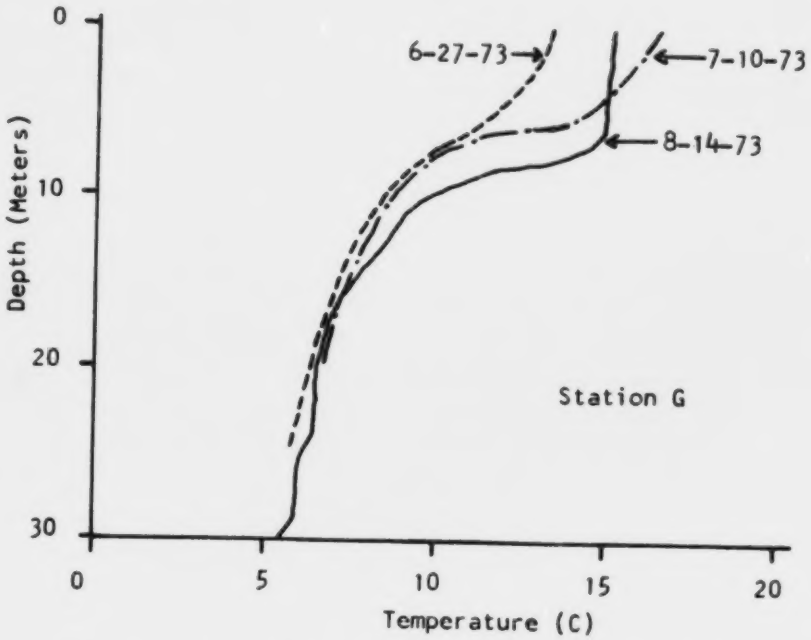


Figure 5 Temperature profiles, Dillon Reservoir, Sampling Station G.

Table 4 Penetration Depths (Feet and Meters) for the One Percent Level of Light (Euphotic Zone).

Dates	Sampling Stations													
	A		B		C		D		E		F		G	
	Ft.	M	Ft.	M	Ft.	M	Ft.	M						
6/29	22.0	6.7	21.0	6.4	20.0	6.1	23.0	7.0	23.5	7.2	21.5	6.6	25.0	7.6
7/09	26.5	8.1	28.0	8.5	24.0	7.3	24.5	7.5						
7/10									29.5	9.0	28.5	8.6	29.5	9.0

Table 5 Phytoplankton Data, Dillon Reservoir, July, 1973

Station	Depth	Number per Milliliter			
		Green	Diatoms	Misc.	Total
A	Surface	40	1543	69	1652
	9	--	3266	132	3398
	18	--	1691	58	1749
B	Surface	30	1832	74	1936
	9	12	3179	137	3328
	18	45	2560	164	2769
	27	--	2027	116	2143
C	Surface	53	1917	116	2086
	8	--	2827	137	2964
	16	11	2258	106	2375
	24	--	1532	85	1617
D	Surface	44	1761	114	1919
	8	6	2772	100	2878
	16	28	3005	185	3218
	24	--	1812	106	1918
E	Surface	33	1225	90	1348
	9	--	2353	19	2372
	18	6	1703	106	1815
	27	11	1586	74	1671
F	Surface	22	1614	156	1792
	9	6	2607	216	2829
	18	11	2433	148	2581
	27	--	1491	95	1586
G	Surface	28	1745	127	1900
	9	--	2684	221	2905
	18	6	2347	164	2517
	27	11	1843	100	1954

Lackey (1945), as that point when an organism reaches or exceeds 500 cells per ml. then a bloom was in existance at the time of sampling.* The existance of diatom blooms in Dillon Reservoir represents a biological warning of increasing enrichment and indicates the progression of the reservoir toward a eutrophic state. As the enrichment progresses a second stage of development will probably be indicated by blooms of green filamentous algae and a decrease in dissolved oxygen in the hypolimnion resulting from the death and decay of large numbers of algae following a bloom.

Mining activities in the Blue River - Dillon Reservoir system, particularly in the Ten Mile Creek watershed, have caused elevated levels of molybdenum to occur in Dillon Reservoir. Molybdenum, a trace element occurring widely in nature, is important in agriculture since it is considered an essential micronutrient for both plants and animals and because it can be concentrated by plants to levels which are toxic to animals. Due to the toxic effects on livestock ingesting the forage grown in soils with high molybdenum levels, criteria have been proposed to limit the maximum concentration of molybdenum in water for continuous irrigation to 10 µg/1 and the maximum acceptable concentration in irrigation water for short term application on soils that react with this element to 50 µg/1.** Because of the numerous factors known to influence the metabolism of molybdenum in animals and man, no limits of acceptability are prescribed for molybdenum concentrations in livestock drinking water or sources of public water supplies, however some long term effects have been observed in mice and rats receiving 10,000 µg/1 molybdenum in drinking water.***

To determine the molybdenum level in Dillon Reservoir, samples for molybdenum analysis were collected at each reservoir cross-section.

* Mackenthun, K.M. 1965. Nitrogen and Phosphorus in Water. An Annotated Selected Bibliography of Their Biological Effects. U.S. Dept. of Health, Education, and Welfare, Public Health Service, 111 pp.

** Proposed Criteria For Water Quality - Volume I. Op.cit.

*** Chappell, W.R. 1973. Transport and the Biological Effects of Molybdenum in the Environment. Presented at Heavy Metals in the Aquatic Environment Conference, Vanderbilt University, Nashville, Tennessee, 45 pp.

The range of concentrations and average level found at each cross-section were:

Section	A	B	C	D	E	F	G
Range	200-410	215-440	205-440	215-465	230-500	255-400	235-435
Average	314	342	322	351	339	320	338

(All concentrations in µg/l molybdenum)

Results show the level of molybdenum in the reservoir greatly exceeds the proposed criteria for irrigation use with concentrations ranging from 205 µg/l to 465 µg/l. While the highest average level of 351 µg/l molybdenum occurred at the cross-section at the outlet of the Ten Mile Creek Arm (Section D) of the reservoir, the overall average concentration of molybdenum at the reservoir cross-sections appeared to be in the 315-350 µg/l range. Furthermore, the molybdenum appeared to concentrate nearer the bottom of the reservoir with the exception of the Ten Mile Creek Inlet (Section C) where the higher concentration appeared at the surface (Appendix Tables A-2 to A-22). Although the molybdenum levels in Dillon Reservoir are considerably less than the 10,000 µg/l found to affect rats and mice, water from the reservoir if used for irrigation of lands for the growth of forage crops may present a toxicity problem to livestock.

II. Organic and Nutrient Loading From Major Tributaries

To determine the organic and nutrient contribution from the major tributaries to Dillon Reservoir, sampling stations were located on the three major tributaries feeding the reservoir at locations just prior to discharge to the reservoir (Appendix Table A-1). These tributaries, the Blue River, Snake River, and Ten Mile Creek were sampled over three-day sampling periods during June, July and August, 1973.

The greatest contribution of 5-day biochemical oxygen demanding material from these three tributaries during this study came in June when the total loading of BOD_5 from the Blue and Snake Rivers and Ten Mile Creek was 2368, 735 and 2173 kg/day (5216, 1620 and 4787 lbs/day) respectively. This organic loading decreased by a third to a half in July and decreased still further in August when the loading from the Blue and Snake Rivers and Ten Mile Creek was 66, 82 and 39 kg/day (146, 181 and 86 lbs/day) respectively (Table 6).

The 0.05 mg/l maximum allowable concentration for total phosphorus in streams entering lakes and reservoirs was exceeded in only one sample from the major tributaries during the study. This single occurrence was a 0.06 mg/l value in June from Ten Mile Creek. The

TABLE 6

Organic and Nutrient Loading from Major Tributaries

		June			July			August		
		Blue	Snake	Ten Mile	Blue	Snake	Ten Mile	Blue	Snake	Ten Mile
Flow	cfs	483	300	591	288	155	275	90	56	53
	cms	13.5	8.4	16.5	8.1	4 3	7.7	2.5	1.6	1.5
BOD_5	mg/1	2	1	<1.5	<1	<1	<1	0.3	0.6	0.3
TKN	mg/1	0.21	0.15	0.20	0.20	<0.10	0.15	< 0.10	0.25	<0.10
Total-P	mg/1	0.038	0.010	0.017	0.020	<0.010	< 0.005	0.017	0.014	0.008
BOD_5	#/day	5216	1620	4787	1555	837	1485	146	181	86
TKN	#/day	548	243	638	311	84	223	49	76	29
Total-P	#/day	99	16	54	31	8	7	8	4	2
BOD_5	kg/day	2368	735	2173	706	380	674	66	82	39
TKN	kg/day	249	110	290	141	38	101	22	34	13
Total-P	kg/day	45	7	25	14	4	3	4	2	1

remainder of the Ten Mile Creek samples as well as all those from the Blue and Snake Rivers remained at a level less than the 0.05 mg/l maximum.

Greatest total phosphorus contributions during the study came in June when the Blue River contributed 45 kg/day (99 lbs/day) to Dillon Reservoir with Ten Mile Creek discharging 25 kg/day (54 lbs/day) at the same time (Table 6). During this sampling period in June, the Snake River was contributing 7 kg/day (16 lbs/day). In July the contribution from the Blue River decreased to 14 kg/day (31 lbs/day) with the other tributaries decreasing to 3-4 kg/day (7-8 lbs/day). Through August, the total phosphorus contribution from all three tributaries remained at a 1-4 kg/day (2-8 lbs/day) level.

To determine the molybdenum contribution from the tributaries feeding Dillon Reservoir, samples for molybdenum analysis were collected from the Blue River, Snake River and Ten Mile Creek. Ten Mile Creek contained the highest level of molybdenum where concentrations of 75, 83 and 142 µg/l occurred in June, July and August respectively (Appendix Tables A-23 to A-30). Molybdenum concentrations in the Blue and Snake Rivers were consistently less than 10 µg/l. Although the highest concentration (142 µg/l molybdenum) from Ten Mile Creek occurred in August, the greatest contribution to the reservoir came in June when higher flows resulted in a loading of approximately 109 kg/day (239 lbs/day). While both the Blue and Snake Rivers met the proposed molybdenum criteria, Ten Mile Creek if used to irrigate lands for forage crops may present a toxicity problem to livestock.

III. Organic and Nutrient Loading From Wastewater Treatment Facilities

To determine the organic and nutrient loading from municipal wastewater treatment facilities discharging into Dillon Reservoir and its major tributaries, the effluents of five such facilities were sampled over the same sampling period as the tributaries. A sixth treatment facility, the Dillon Wastewater Treatment Plant, was also sampled, but this plant discharges to the Blue River downstream of the dam and does not contribute to the organic and nutrient content of the reservoir.

Of the five plants contributing to the organic and nutrient content of Dillon Reservoir, three plants, Frisco, East Dillon and Summit County #1, discharge effluents directly to the reservoir (Figure 1). The remaining two plants discharge to the Blue River (Breckenridge STP) and Ten Mile Creek (Copper Mountain STP). The loading figures for the Blue River and Ten Mile Creek discussed in the previous section include the total effect of the wastewater treatment plant discharges to these tributaries.

Of those plants discharging directly to the reservoir, the Frisco Wastewater Treatment Plant contributes the greatest organic and phosphorus load, which in most cases is 50 percent or more than the next largest contributor, the Summit County #1 Wastewater Treatment Plant (Tables 7, 8 and 9). Frisco's organic contribution to the reservoir was at its highest in June with a discharge of 16 kg/day (36 lbs/day) 5-day BOD. The greatest phosphorus loading came in August when the plant discharged 3.6 kg/day (8.0 lbs/day) total phosphorus. The largest nitrogen contribution however came in August from the East Dillon (Summit Cove) STP which had a discharge to the reservoir of 12 kg/day (27 lbs/day).

Of the plants not discharging directly to the reservoir, the Breckenridge Wastewater Treatment Plant had, by far, the greatest organic and nutrient contribution to the system. In June, the plant discharged 183 kg/day (404 lbs/day) 5-day BOD, 21 kg/day (46 lbs/day) phosphorus and 40 kg/day (89 lbs/day) nitrogen. These loadings decreased somewhat from these highs for the July and August sampling periods with the exception of nitrogen which increased to 49 kg/day (108 lbs/day) in August. These loadings are reflected in the Blue River contributions to the reservoir discussed earlier. A brief description of the treatment facilities appears in Table A-1, Appendix A.

IV. Algal Growth Potential of Dillon Reservoir - A Laboratory Study

The increasing population growth in the Dillon watershed will increase the need for additional waste water treatment facilities in the area. If adequate nutrient removal in these facilities is not implemented, the subsequent discharges into Dillon Reservoir may cause deterioration in its trophic structure, creating the possibility of nuisance algal blooms and other problems associated with eutrophication.

To investigate the possibility of accelerated eutrophication and assess the impact of nutrient loading on productivity of the reservoir, algal assays were initiated to determine the algal growth potential at present nutrient levels in Dillon Reservoir. Additional algal assays were conducted to determine the effect of the high molybdenum concentrations on algal growth in reservoir waters.

TABLE 7

Organic and Nutrient Loading from Wastewater Treatment Facilities - June

		STP-F	STP-B	STP-ED	STP-S	STP-CM	STP-D
Flow	cfs	0.12	1.41	0.015	0.155	0.09	A
	cms	0.003	0.039	0.0004	0.004	0.002	
BOD_5	mg/l	55	53	<3	25	5	
TKN	mg/l	20	11.7B	21B	5.4B	1.8B	
Total-P	mg/l	8.1	6.0	0.05	3.4	0.34B	
BOD_5	#/day	36	404	<0.2	21	2.4	
TKN	#/day	13	89	1.7	4.5	0.9	
Total-P	#/day	5.2	46	0.004	2.8	0.16	
BOD_5	kg/day	16	183	0.09	9.5	1.1	
TKN	kg/day	5.9	40	0.8	2.0	0.4	
Total-P	kg/day	2.4	21	0.002	1.3	0.07	

A - No sampling

B - Held beyond recommended storage time before processing

TABLE 8

Organic and Nutrient Loading from Wastewater Treatment Facilities - July

		STP-F	STP-B	STP-ED	STP-S	STP-CM	STP-D
Flow	cfs	0.17	1.05	0.001	0.105	0.035	0.06
	cms	0.005	0.029	-	0.003	0.001	0.002
BOD_5	mg/l	22	30	2	20	<1	26
TKN	mg/l	13.8	12B	26.2B	15.4B	1.2B	8.4B
Total-P	mg/l	6.2	4.2	0.035	2.6	0.02	5.1B
BOD_5	#/day	20	170	0.01	11.3	<0.19	8.4
TKN	#/day	12.7	68	0.1	8.7	0.2	2.7
Total-P	#/day	5.7	24	<0.001	1.5	0.004	1.7
BOD_5	kg/day	9.2	77	0.004	5.1	0.09	3.8
TKN	kg/day	5.8	31	0.04	3.9	0.09	1.2
Total-P	kg/day	2.6	11	-	0.7	0.002	0.7

A - No sampling

B - Held beyond recommended storage time before processing

TABLE 9

Organic and Nutrient Loading from Wastewater Treatment Facilities - August

		STP-F	STP-B	STP-ED	STP-S	STP-CM	STP-D
Flow	cfs	0.16	1.12	0.17	0.15	0.065	A
	cms	0.004	0.031	0.005	0.004	0.002	
BOD_5	mg/l	8.7	12	2.6	5.0	1.4	
TKN	mg/l	24	18	29	4.8	0.6	
Total-P	mg/l	9.2	4.1	0.09	0.43	0.04	
BOD_5	#/day	7.5	73	2.4	4.0	0.5	
TKN	#/day	20	108	27	3.9	0.2	
Total-P	#/day	8.0	25	0.08	0.35	0.01	
BOD_5	kg/day	3.4	33	1.1	1.8	0.2	
TKN	kg/day	9.1	49	12	1.8	0.09	
Total-P	kg/day	3.6	11	0.04	0.2	0.006	

A - No Sampling

B - Held beyond recommended storage time before processing

METHODS

Water was collected from three stations on Dillon Reservoir; the Blue River Arm, Frisco Bay (Ten Mile Creek Arm), and the main body of the reservoir during July, 1973 (Figure 1). All water samples were collected approximately one meter (three feet) below the surface, and placed in plastic "Cubitainers". Water samples for nutrient and metals analyses were preserved with 4 ml 1% $HgCl_2$ liter^{-1} and 5 ml concentrated HNO_3 liter^{-1}, respectively. Samples were refrigerated during transportation to the laboratory. Algal assay test water was filtered through a 0.45 μ membrane filter, and frozen until each assay was conducted. Results of nutrient and metals analyses are presented in Table 10.

All algal assays were conducted following the procedures outlined in Algal Assay Procedure, Bottle Test (EPA, 1971).* Selenastrum capricornutum Printz was used as the test algal. Assays were conducted in triplicate using 250 ml wide mouth Erlenmeyer Flasks, each flask containing 100 ml total volume of culture. Test cultures were inoculated from two week old stock cultures. All flasks were incubated for seven days in a constant temperature water bath at 24 ± 0.5 C (Figure 6). Compressed air was bubbled through each culture at a rate of 500 ml minute^{-1} ± 10% (Figure 7) to maintain (a pH of 8.5 or less) preventing possible carbon limitation. All flasks were illuminated with cool-white fluorescent lighting of 400 ft-c (4304 lux).

Additions to the lake water of phosphorus (as K_2HPO_4) and nitrogen (as Na_2NO_3) were made singly or in combination of the two nutrients at concentrations (mg liter^{-1}) of: 0.005 P, 0.01 P, 0.05 P, 0.01 N, 0.05 N, 0.1 N, 0.005 P + 0.01 N, 0.005 P + 0.05 N, 0.005 P + 0.1 N, 0.01 P + 0.01 N, 0.01 P + 0.1 N, 0.05 P + 0.01 N, 0.05 P + 0.05 N, 0.05 P + 0.1 N. For the molybdenum assays, molybdenum (as $Na_2MoO_4 \cdot 2H_2O$) was added to the lake water at concentrations of 300 and 600 μg Mo liter^{-1}. Water from each station, inoculated with the test alga but no nutrients, was used as each respective control. Without addition of nutrients or molybdenum to the cultures a fluctuation of more than 0.5 pH units from that of the natural water was observed.

Algal growth was measured using a Turner Model 111 Fluorometer to determine the chlorophyll a concentrations following each day of incubation. The fluorometer was calibrated for chlorophyll analysis using the methods outlined by Strickland and Parsons (1968).**

* Environmental Protection Agency, National Eutrophication Research Program. 1971. Algal Assay Procedure, Bottle Test. EPA. Corvallis. 82 pp.

** Strickland, J.D.H. and T.R. Parsons. 1968. Fluorometric Determination of Chlorophylls. A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada. Bull. 167:201-202

TABLE 10

Chemical Properties of Surface Water Collected From
Dillon Reservoir in July, 1973

Parameter* \ Station Location	Blue River Arm	Frisco Bay	Main Reservoir Body
pH	7.5	7.6	8.1
NO_3-N	0.04	<0.01	0.02
NH_3-N	<0.01	<0.01	<0.01
TKN-N	0.30	0.20	0.10
PO_4-P	0.006	<0.005	<0.005
Total-P	0.018	0.016	0.012
Mo	.248	.290	.290
Total Fe	.065	.055	.035

* All figures except pH are expressed as mg liter $^{-1}$.

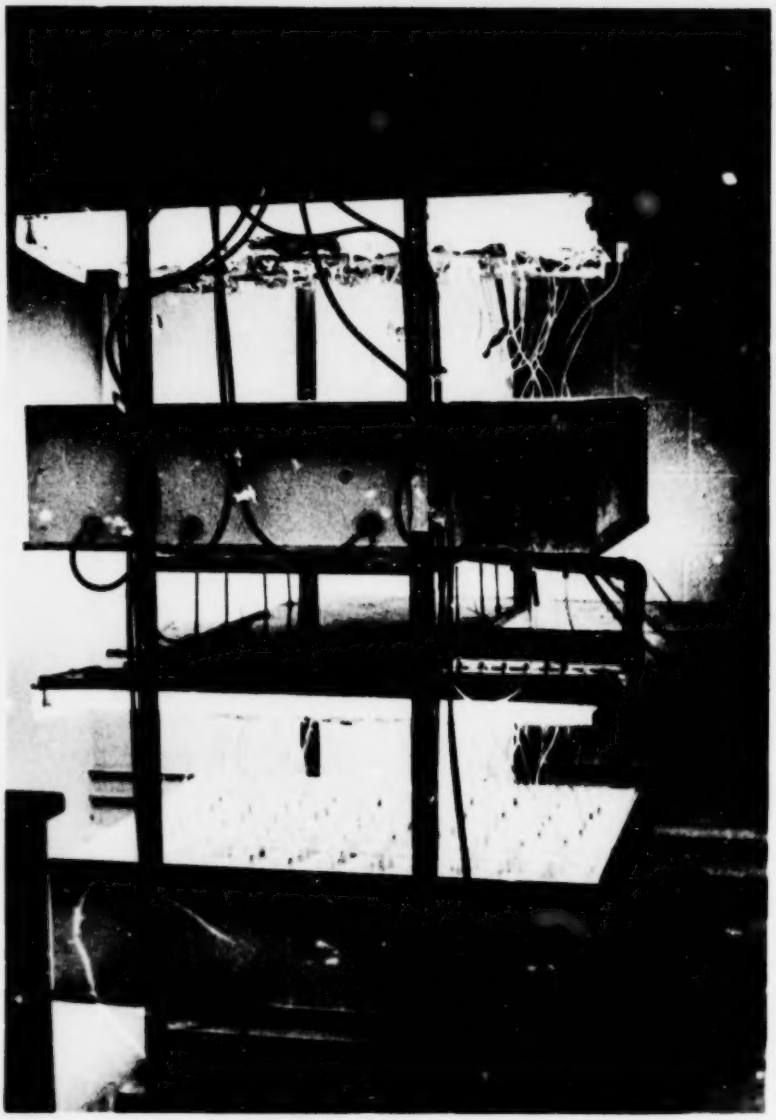


Figure 6. Constant temperature water baths containing culture flasks.

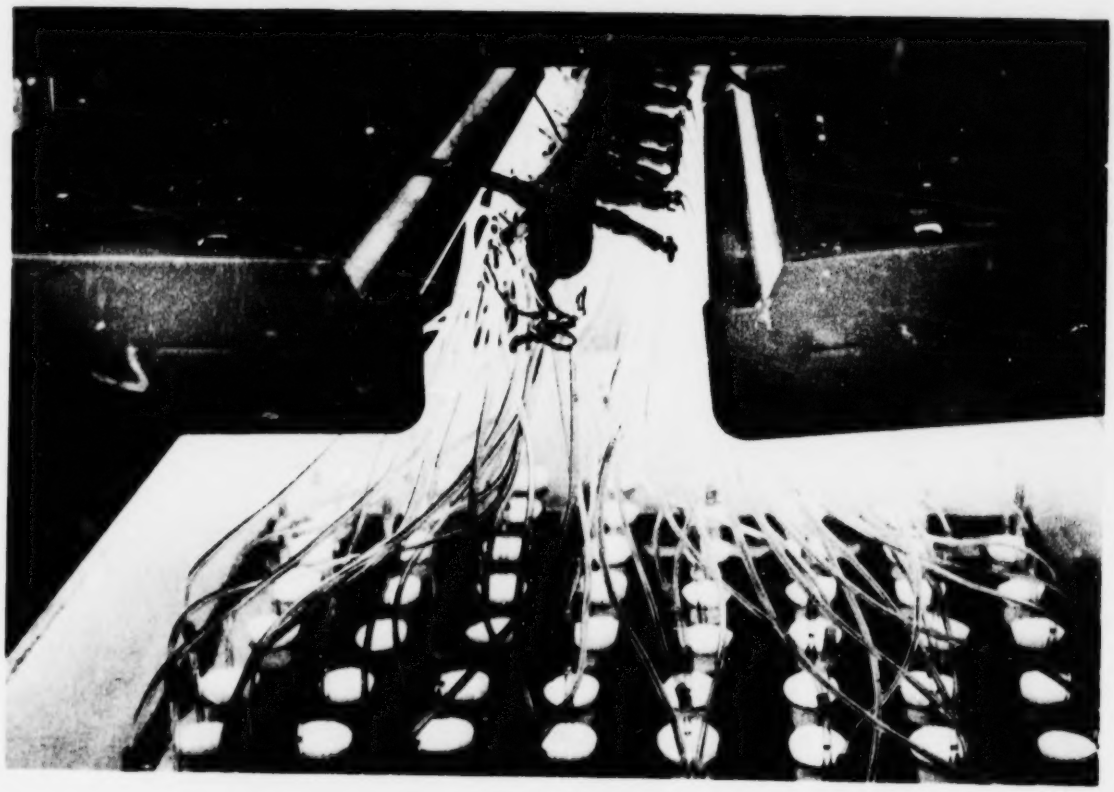


Figure 7. Air delivery system for culture flasks.

RESULTS OF STUDY

Figures 8 - 10 illustrate the growth response of S. capricornutum to nutrient additions to water collected from the three sampling stations in Dillon Reservoir. The growth rate was calculated using the following equation:

$$K = \frac{\log_e (X_1/X_2)}{t_2 - t_1} \quad \text{days}^{-1}$$

where X_1 and X_2 are the chlorophyll a concentrations in mg liter^{-1} at times t_1 and t_2 in days.

Figure 8 shows the growth response of S. capricornutum to nutrient additions to water taken from the Blue River Arm of Dillon Reservoir. In general, individual spikes of phosphorus resulted in noticeable higher growth rates from the control than did individual nitrogen spikes.

Growth response of S. capricornutum to nutrient additions to water taken from Frisco Bay and the main body of the reservoir are shown in Figures 9 and 10, respectively. The results are similar to those previously reported for the Blue River Arm. Individual spikes of phosphorus produced markedly higher growth rates than controls and individual nitrogen spike levels. Combined spikes of nitrogen and phosphorus further increased algal growth rates from those of individual phosphorus spikes.

The reason for the relatively large growth rate at 0.1 mg N liter^{-1} in water collected from the Blue River Arm is not known. As can be seen in Figures 9 and 10, the algal growth rate at 0.1 mg N liter^{-1} in water collected from the other two stations was not markedly different from growth experienced at the lower nitrogen concentrations tested. Nitrogen spiked samples also exhibited consistently lower growth rates than lake water controls. The reason for this phenomenon is unknown.

Experimental results reported here (Figures 8 - 10) indicate that algal growth in Dillon water is presently limited by inadequate concentrations of phosphorus. Algal growth rates resulting from individual phosphorus spikes to lake water were noticeably higher than either growth rates in the respective controls or growth rates obtained from nitrogen spikes. This situation however, may be altered to a nitrogen limiting condition by the on-going loading of phosphorus into the reservoir. Combined nitrogen-phosphorus additions to the test water generally resulted in higher algal growth rates than those obtained from individual phosphorus spikes. Results of this study indicate that nitrogen addition to the reservoir water, at currently existing nutrient levels, would have little or no stimulatory effect on algal growth. Loading of nitrogen in

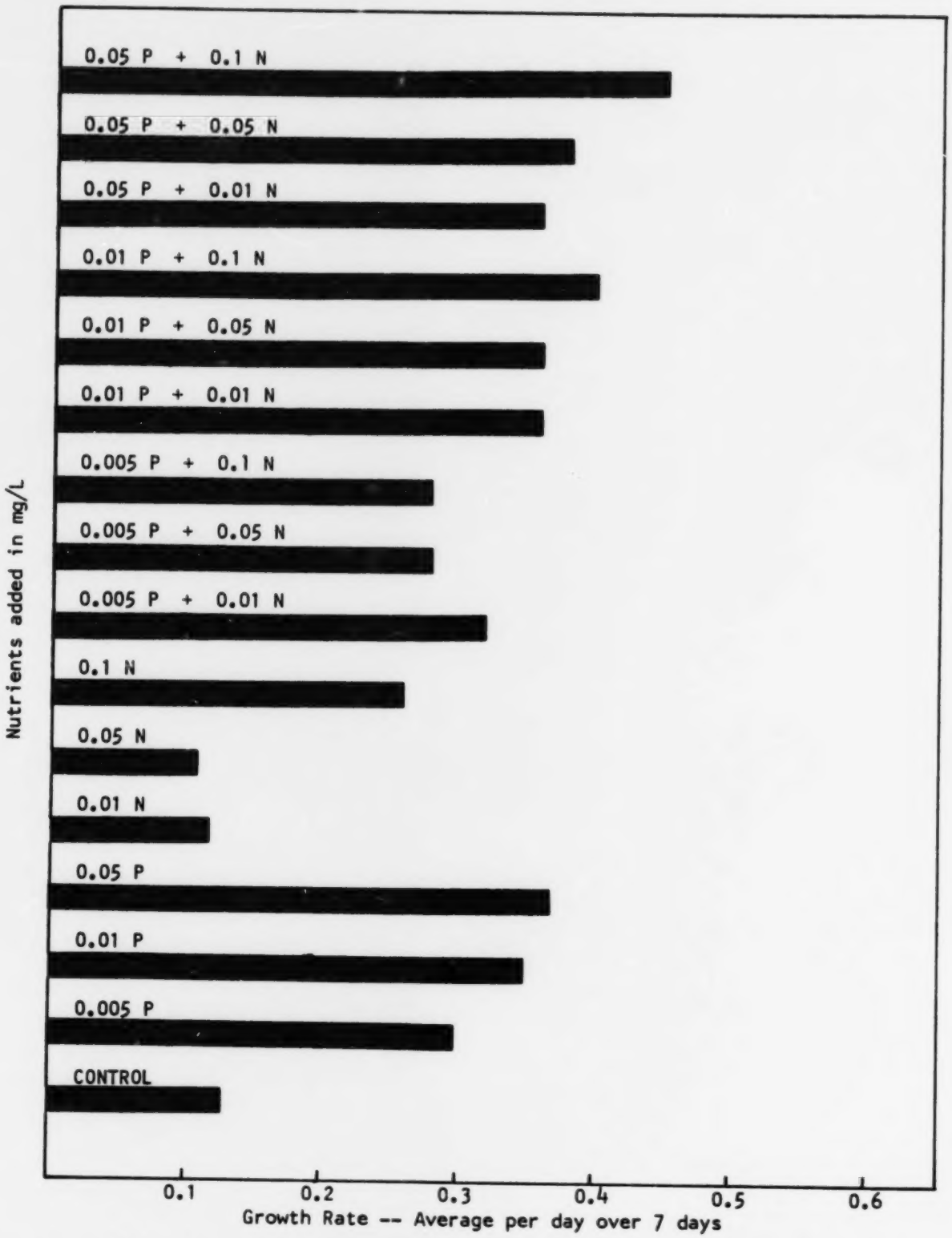


Figure 8. Effect on growth of S. capricornutum of various nutrient additions to water taken from the Blue River Arm of Dillon Reservoir.

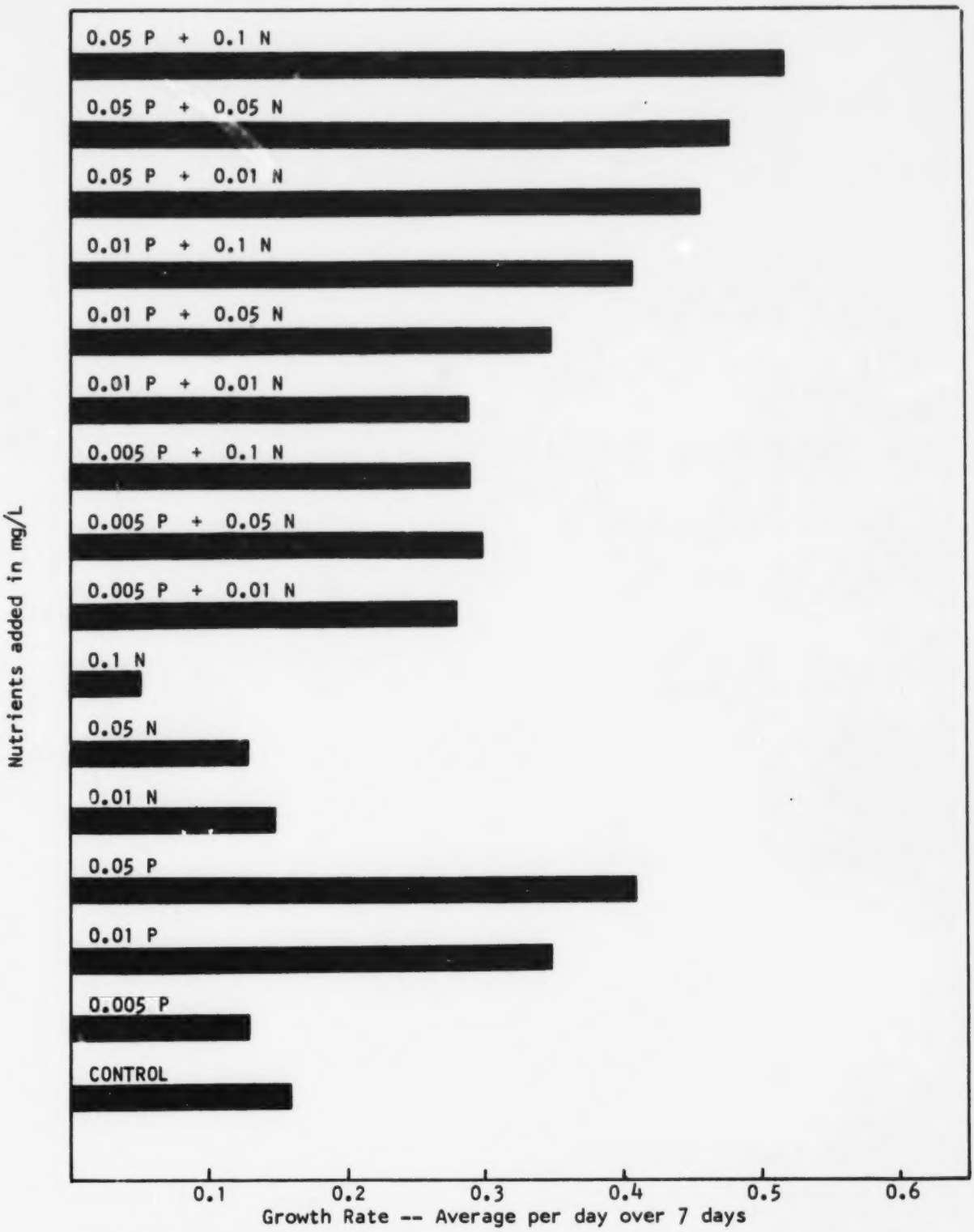


Figure 9. Effect on growth of S. capricornutum of various nutrient additions to water taken from Frisco Bay of Dillon Reservoir.

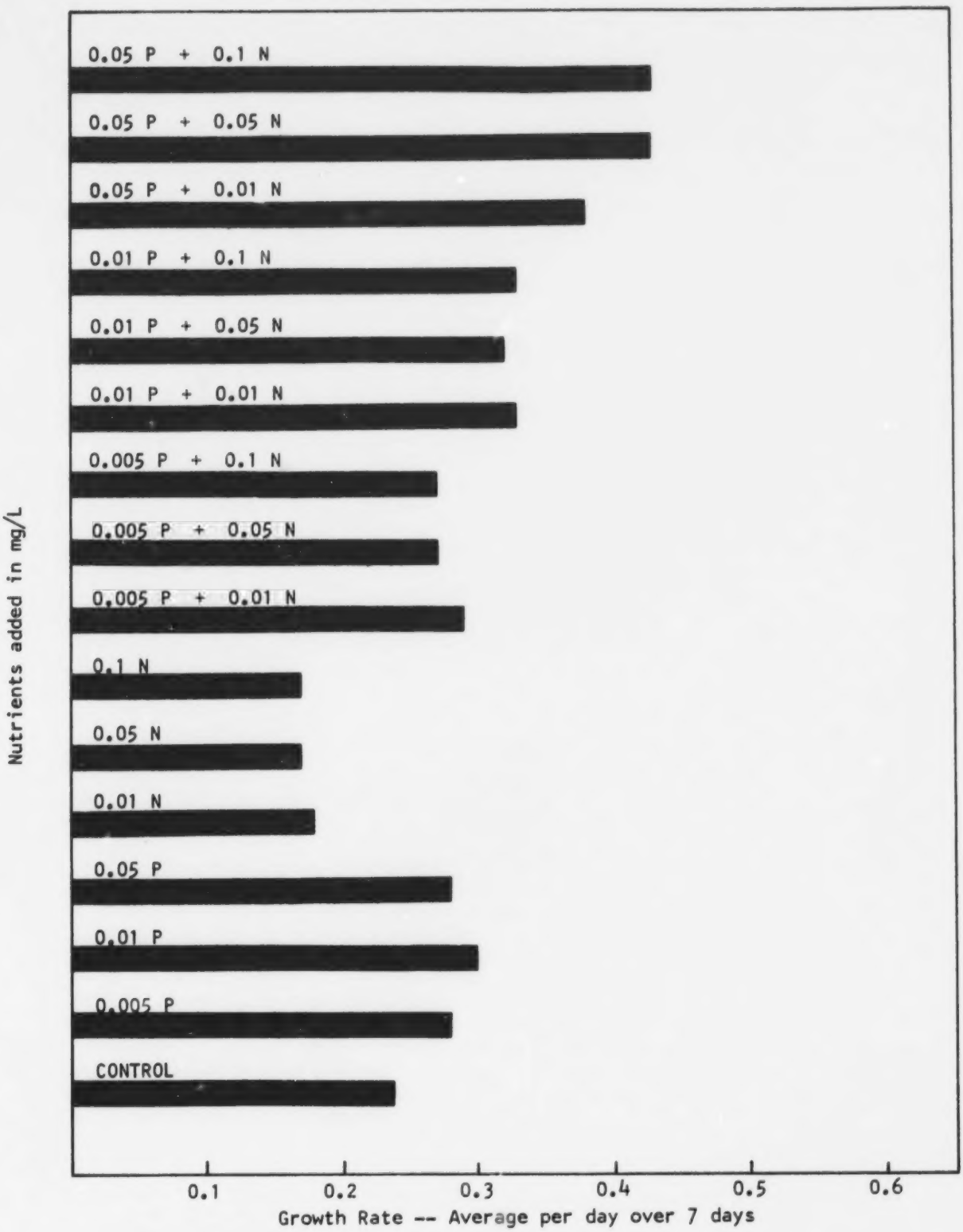


Figure 10. Effect on growth of S. capricornutum of various nutrient additions to water taken from the main body of Dillon Reservoir.

conjunction with phosphorus, however, would likely result in a greater algal growth potential in the reservoir, than if phosphorus were the sole contributing nutrient.

Results of the molybdenum algal assay are presented in Figure 11. No significant difference in growth rate of S. capricornutum was observed between the molybdenum spikes and the respective control water from each station. Results indicate the concentrations of molybdenum existing in Dillon Reservoir likely would not have any stimulatory or inhibitory effect on the growth of algal populations.

Direct correlation between naturally occurring situations and laboratory controlled algal assays is difficult. Factors such as light intensity and water temperature, which were maintained in the laboratory at optimal levels for the test species, could be expected to vary greatly in nature.

Correlation between the growth physiology of laboratory test species and indigenous algal in Dillon Reservoir is equally difficult. Although Selenastrum sp. was observed in lake water samples, diatoms are the prevalent form of algae inhabiting Dillon Reservoir. At the present time, however, algal assay procedures for diatoms have not been established. Of the three algal species suggested in Algal Assay Procedure, Bottle Test (EPA, 1971), S. capricornutum was felt best suited for correlation to the existing conditions in Dillon Reservoir.* The results obtained using S. capricornutum indicated that additions of phosphorus to Dillon Reservoir would result in increased algal growth. Additional loading of nitrogen in combination with phosphorus could be expected to further stimulate algal growth.

* Algal Assay Procedure, Bottle Test. Op.cit.

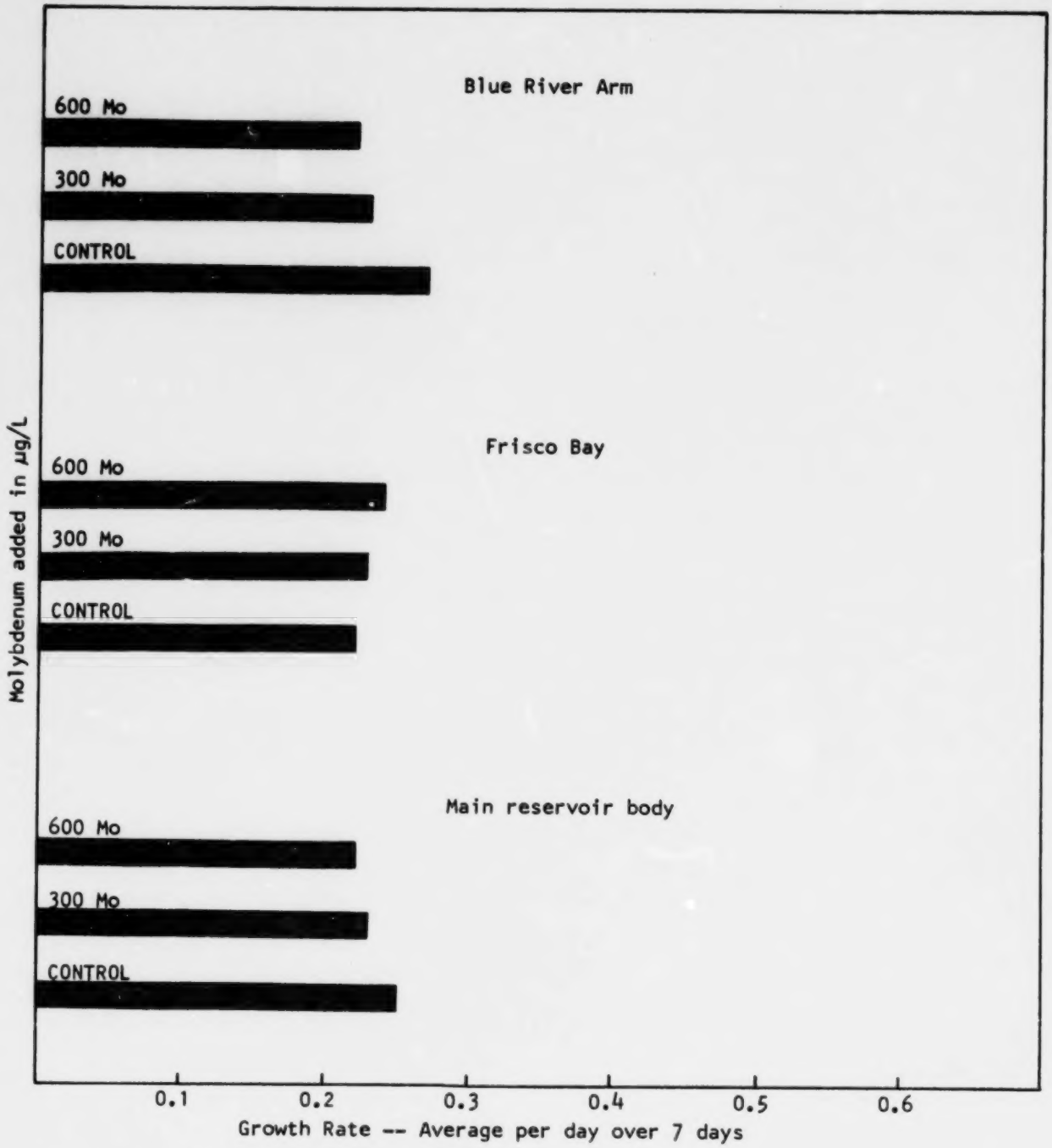


Figure 11. Effect on growth of S. capricornutum of molybdenum addition to water taken from the Blue River Arm, Frisco Bay, and the main body of Dillon Reservoir.

SUMMARY AND CONCLUSIONS

To determine existing nutrient levels in Dillon Reservoir and the organic and nutrient contributions from the major tributaries and municipal wastewater treatment facilities discharging into the reservoir, an investigation of the Blue River - Dillon Reservoir system was initiated. The study was conducted over three-day sampling periods during the months of June, July and August, 1973. To further determine the probable consequences of increased nutrient and molybdenum levels in Dillon Reservoir relating to nuisance algal growths, a laboratory study of the algal growth potential of the reservoir was conducted.

The results of the survey indicate that the nitrogen concentrations, although present at significant levels in the reservoir, are not yet considered excessive. Phosphorus concentrations remained at levels less than the 0.05 mg/l recommended limit with the exception of two locations in the reservoir, the outlets of the Blue River Arm and Dillon Bay, Sections B and G.

These nutrients, along with other elements, contributed to a phytoplankton growth in Dillon Reservoir which indicates that the oligotrophic state of the reservoir is beginning to change to a more enriched body of water. Under the general definition of an algal bloom proposed by Lackey (1945), an algal bloom was in existance during the July portion of the study. The presence of diatom blooms in the reservoir is a warning of the increased enrichment and indicates the progression of the reservoir toward a eutrophic state. If this progression continues, a second stage of development will probably occur, indicated by blooms of green filamentous algae accompanied by a decrease in the dissolved oxygen level in the hypolimnion resulting from the death and decay of large numbers of algae following a bloom.

Algal assays conducted on water from three locations in Dillon Reservoir indicated a phosphorus limiting condition to exist at the present time. Algal growth rates were determined by adding phosphorus and nitrogen, singly and in combination, to water samples from these locations. Single additions of phosphorus resulted in stimulated algal growth rates, while additions of nitrogen caused little or no increase in growth rate from control samples.

High levels of molybdenum were found at all cross-sections of Dillon Reservoir with the highest average level occurring at the outlet of the Ten Mile Creek Arm (Section D). Concentrations at the cross-sections averaged between 314 µg/l to 351 µg/l with the highest levels occurring nearer the bottom. Molybdenum concentrations in the Blue and Snake Rivers were consistently less than 10 µg/l, however high levels of molybdenum occurred in Ten Mile Creek throughout the study with the highest average concentration (142 µg/l) occurring in August. While both the Blue and Snake Rivers met the proposed molybdenum criteria for irrigation use, water from Ten Mile Creek and Dillon Reservoir if used to irrigate lands for forage crops may present a toxicity problem to livestock.

Results of the molybdenum algal assay showed no significant difference in growth rate between samples spiked with molybdenum and control samples indicating that the existing molybdenum concentrations in Dillon Reservoir would not likely have any stimulatory or inhibitory effect on the growth of algal populations in the reservoir.

Greatest organic loading to Dillon Reservoir from a tributary, as measured by the 5-day biochemical oxygen demand (BOD), came in June with a contribution of 2368 kg/day (5216 lbs/day) from the Blue River. Ten Mile Creek and the Snake River contributed lesser amounts, 2173 and 735 kg/day (4787 and 1620 lbs/day) respectively. Loadings from the tributaries decreased a third to a half in July and still further in August.

Greatest phosphorus loading to Dillon Reservoir from a tributary also came from the Blue River when in June, the river contributed 45 kg/day (99 lbs/day) phosphorus.

Five wastewater treatment plants contribute to the organic and nutrient levels in Dillon Reservoir. Three of these plants, Frisco, East Dillon and Summit County #1 discharge effluents directly to the reservoir. The remaining plants, Breckenridge and Copper Mountain discharge to the Blue River and Ten Mile Creek respectively. The Frisco STP, of the three plants discharging directly to the reservoir, contributed the greatest organic and phosphorus loads during the study of 16 kg/day (36 lbs/day) 5-day BOD in June, and 3.6 kg/day (8.0 lbs/day) phosphorus in August. The largest nitrogen contributor was the East Dillon (Summit Cove) STP which discharged 12 kg/day (27 lbs/day) to the reservoir in August.

Of the plants not discharging directly to Dillon Reservoir, the Breckenridge STP had, by far, the greatest organic and nutrient contribution to the Blue River - Dillon Reservoir system. Loadings to the Blue River of 183 kg/day (404 lbs/day) 5-day BOD and 21 kg/day (46 lbs/day) phosphorus occurred in June and 49 kg/day (108 lbs/day) nitrogen occurred in August. These loadings are included in the contributions from the Blue River discussed earlier.

APPENDIX A

SURVEY DATA

TABLE A-1

WATER QUALITY SAMPLING STATION LOCATIONS

DILLON RESERVOIR - BLUE RIVER, COLORADO

Station No.	Description
	Reservoir Stations
Section A-A	Blue River arm at Silver Dollar Island.
Section B-B	Outlet of Blue River arm.
Section C-C	Frisco Bay, Ten Mile Creek arm.
Section D-D	Outlet of Ten Mile Creek arm.
Section E-E	Outlet of Snake River arm.
Section F-F	Outlet of Dillon Bay.
Section G-G	Main reservoir - Overlook to West Portal.
	Stream Stations
BR-1	Blue River about 0.3 miles (0.48 km) downstream from Dillon Dam on west bank under I-70 bridge.
BR-2	Blue River about 2 miles (3.2 km) upstream from confluence with Dillon Reservoir at USGS gaging station - about 0.3 miles (0.48 km) downstream from Swan River.
BR-3	Blue River headwaters (Bemrose Creek) - 200 yards (183 meters) South on dirt road from bottom of first switchback as Highway 6 begins climb over Hoosier Pass.
SR-1	Snake River prior to confluence with Dillon Reservoir at U.S. Highway 6 Bridge.
SR-2	Snake River mainstem - at wooden bridge about 4 miles (6.4 km) upstream from confluence with North Fork Snake River and USGS gaging station.

TM-1	Ten Mile Creek prior to confluence with Dillon Reservoir at Highway 9 bridge at Southwest edge of Frisco.
TM-2	Ten Mile Creek - upstream control station - at first bridge on Highway 91 about 8 miles (12.9 km) upstream from intersection of Highways 91 & 6.

Wastewater Treatment Plant Stations

STP-F	Frisco Wastewater Treatment Plant - activated sludge with polishing pond - discharge to Dillon Reservoir at east side of Frisco.
STP-B	Breckenridge Wastewater Treatment Plant - Oxidation ditch - discharge to Blue River about 0.5 miles (0.8 km) downstream from Breckenridge city limits.
STP-S	Summit County # 1 Wastewater Treament Plant - activated sludge with tertiary filter - discharge via open ditch to Dillon Reservoir near Summit County High School at northeast side of Frisco.
STP-ED	East Dillon (Summit Cove) Wastewater Treatment Plant - tertiary package plant - discharge to Snake River inlet to Dillon Reservoir.
STP-CM	Copper Mountain Wastewater Treatment Plant - tertiary package plant - discharge to Ten Mile Creek near junction of Highways 6 & 91.
STP-D	Dillon Wastewater Treatment Plant - oxidation pond - discharge to Blue River about 1 mile (1.6 km) downstream from Dillon Dam.

Table A-2

DILLON -- BLUE RIVER STUDY

Station: A-1 Dillon Reservoir Section A

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1655			1655			1655		
Depth	Meters	S			7			14		
Temp	Cent.	13.9			9.5			7.1		
pH	SU	8.45			8.4			7.7		
DO	mg/l	9.0			9.2			8.7		
Molybdenum	µg/l	340			315			390		
T. Iron	µg/l	75			70			70		
TKN	mg/l	0.20			0.20			0.20		
NO_3-N	mg/l	0.03			0.03			0.07		
NH_3-N	mg/l	<0.01			<0.01			0.01		
Total-P	mg/l	0.005			0.013			0.014		
Ortho-P	mg/l	<0.005			<0.005			<0.005		

Table A-3

DILLON -- BLUE RIVER STUDY

Station: A-2 Dillon Reservoir Section A

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1630	1240	1345	1630	1240	1345	1630	1240	1345
Depth	Meters	S	S	S	8	8	8	18	15	18
Temp	Cent.	13.0	17.0	16.0	9.4	10.5	14.5	6.4	8.5	7.5
pH	SU	7.5	-	7.7	8.1	8.2	7.4	7.75	7.5	7.2
DO	mg/l	9.0	-	7.8	9.1	7.5	7.8	9.0	7.5	6.6
Molybdenum	µg/l	315	248	200	275	240	215	410	375	395
T. Iron	µg/l	60	65	20	95	55	15	50	65	15
TKN	mg/l	0.20	0.30	0.20	0.20	0.20	0.20	0.20	0.20	0.20
NO_3-N	mg/l	0.03	0.04	<0.01	0.03	0.02	0.01	0.07	0.08	0.12
NH_3-N	mg/l	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01	0.03	0.02
Total-P	mg/l	0.009	0.018	0.012	0.012	0.016	0.013	0.011	0.015	0.012
Ortho-P	mg/l	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Table A-4

DILLON -- BLUE RIVER STUDY

Station: A-3 Dillon Reservoir Section A

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1645			1645			1645		
Depth	Meters	S			8			18		
Temp	Cent.	13.0			9.4			6.4		
pH	SU	8.3			8.05			7.5		
DO	mg/l	9.0			9.0			8.4		
Molybdenum	µg/l	345			-			330		
T. Iron	µg/l	55			80			75		
TKN	mg/l	0.20			0.20			0.20		
NO_3-N	mg/l	0.03			0.03			0.09		
NH_3-N	mg/l	<0.01			<0.01			0.02		
Total-P	mg/l	0.009			0.007			0.007		
Ortho-P	mg/l	<0.005			<0.005			<0.005		

Table A-5

DILLON -- BLUE RIVER STUDY

Station: B-1 Dillon Reservoir Section B

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	0925			0925			0925		
Depth	Meters	S			7			35		
Temp	Cent.	13.4			10.1			-		
pH	SU	8.4			8.2			7.5		
DO	mg/l	8.8			8.8			8.2		
Molybdenum	µg/l	410			320			375		
T. Iron	µg/l	65			85			45		
TKN	mg/l	0.30			0.30			0.30		
NO_3-N	mg/l	0.03			0.04			0.06		
NH_3-N	mg/l	<0.01			<0.01			0.01		
Total-P	mg/l	0.007			0.022			0.180		
Ortho-P	mg/l	<0.005			<0.005			0.170		

Table A-6

DILLON -- BLUE RIVER STUDY

Station: B-2 Dillon Reservoir Section B

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1000	1400	1320	1000	1400	1320	1000	1400	1320
Depth	Meters	S	S	S	7	8	8	35	25	25
Temp	Cent.	12.9	15.5	15.5	9.9	11.0	12.0	-	6.5	6.5
pH	SU	7.8	8.1	7.6	7.7	7.4	7.6	6.85	7.5	7.3
DO	mg/l	8.8	7.5	6.8	8.8	8.2	7.6	8.1	7.8	7.3
Molybdenum	µg/l	400	265	215	320	320	220	360	410	415
T. Iron	µg/l	55	50	20	65	60	20	50	25	15
TKN	mg/l	0.50	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
NO_3-N	mg/l	0.04	0.02	<0.01	0.08	0.05	<0.01	0.14	0.07	0.14
NH_3-N	mg/l	0.03	<0.01	0.02	0.01	0.01	<0.01	0.03	<0.01	<0.01
Total-P	mg/l	0.015	0.017	0.010	0.010	0.021	0.012	0.013	0.015	0.010
Ortho-P	mg/l	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Table A-7

DILLON -- BLUE RIVER STUDY

Station: B-3 Dillon Reservoir Section B

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1030			1030			1030		
Depth	Meters	S			7			35		
Temp	Cent.	14.5			11.0			-		
pH	SU	7.9			7.3			7.1		
DO	mg/l	8.8			8.8			8.4		
Molybdenum	µg/l	390			265			440		
T. Iron	µg/l	70			65			45		
TKN	mg/l	0.30			0.20			0.10		
NO_3-N	mg/l	0.81			0.06			0.13		
NH_3-N	mg/l	0.01			<0.01			0.03		
Total-P	mg/l	0.010			0.011			0.012		
Ortho-P	mg/l	<0.005			<0.005			<0.005		

Table A-8

DILLON -- BLUE RIVER STUDY

Station: C-1 Dillon Reservoir Section C

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1555			1555			1555		
Depth	Meters	S			6			10		
Temp	Cent.	13.8			12.4			10.6		
pH	SU	8.3			8.0			7.75		
DO	mg/l	9.0			9.1			9.1		
Molybdenum	µg/l	400			360			260		
T. Iron	µg/l	115			110			160		
TKN	mg/l	0.30			0.30			0.20		
NO_3-N	mg/l	0.04			0.04			0.05		
NH_3-N	mg/l	<0.01			<0.01			<0.01		
Total-P	mg/l	0.018			0.014			0.010		
Ortho-P	mg/l	0.005			<0.005			<0.005		

Table A-9

DILLON -- BLUE RIVER STUDY

Station: C-2 Dillon Reservoir Section C

Date	Mo/Day/Yr	06/29/73	07/10/73	08/16/73	06/29/73	07/10/73	08/16/73	06/29/73	07/10/73	08/16/73
Time	Mtly	1545	1030	1445	1545	1030	1445	1545	1030	1445
Depth	Meters	S	S	S	6	7	6	10	10	10
Temp	Cent.	13.6	17.2	16.0	12.1	10.5	14.0	9.4	8.0	10.2
pH	SU	7.4	7.6	7.6	7.5	7.7	7.6	7.65	7.3	7.5
DO	mg/l	9.1	6.2	7.6	9.0	6.0	7.5	8.8	5.8	-
Molybdenum	µg/l	410	-	215	390	225	205	290	440	205
T. Iron	µg/l	90	55	45	135	105	75	485	80	115
TKN	mg/l	0.20	0.20	0.20	0.20	0.20	0.20	0.30	0.20	0.20
NO_3-N	mg/l	0.04	<0.01	<0.01	0.04	0.02	<0.01	0.06	0.10	0.03
NH_3-N	mg/l	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.03	0.01
Total-P	mg/l	0.031	0.016	0.012	0.014	0.024	0.018	0.014	0.018	0.029
Ortho-P	mg/l	0.020	<0.005	<0.005	0.005	0.007	0.005	0.005	<0.005	0.017

Table A-10

DILLON -- BLUE RIVER STUDY

Station: C-3 Dillon Reservoir Section C

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1605			1605			1605		
Depth	Meters	S			6			10		
Temp	Cent.	13.8			11.8			9.7		
pH	SU	8.25			7.65			7.5		
DO	mg/l	9.0			9.0			8.7		
Molybdenum	µg/l	385			420			310		
T. Iron	µg/l	110			100			175		
TKN	mg/l	0.20			0.20			0.20		
NO_3-N	mg/l	0.03			0.04			0.06		
NH_3-N	mg/l	<0.01			<0.01			0.02		
Total-P	mg/l	0.013			0.015			0.023		
Ortho-P	mg/l	0.006			0.005			0.006		

Table A-11

DILLON -- BLUE RIVER STUDY

Station: D-1 Dillon Reservoir Section D

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1515			1515			1515		
Depth	Meters	S			7			9		
Temp	Cent.	15.1			10.3			9.9		
pH	SU	8.4			7.7			7.5		
DO	mg/l	9.2			8.6			8.8		
Molybdenum	µg/l	355			360			410		
T. Iron	µg/l	85			60			105		
TKN	mg/l	0.20			0.20			0.20		
NO_3-N	mg/l	0.04			0.08			0.10		
NH_3-N	mg/l	<0.01			0.02			0.02		
Total-P	mg/l	0.008			0.008			0.006		
Ortho-P	mg/l	<0.005			<0.005			<0.005		

Table A-12

DILLON -- BLUE RIVER STUDY

Station: D-2 Dillon Reservoir Section D

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1455	1550	1500	1455	1550	1500	1455	1550	1500
Depth	Meters	S	S	S	7	8	8	24	25	20
Temp	Cent.	16.0	15.8	16.5	13.8	11.2	10.0	10.4	7.0	6.5
pH	SU	8.35	8.25	7.5	7.7	8.0	7.2	7.6	8.1	7.1
DO	mg/l	9.1	7.6	7.7	8.8	7.5	7.8	8.5	7.6	-
Molybdenum	ug/l	425	290	215	380	460	215	270	280	365
T. Iron	ug/l	85	55	40	75	50	50	60	65	15
TKN	mg/l	0.30	0.30	0.10	0.30	0.20	0.20	0.30	0.10	0.10
NO_3-N	mg/l	0.04	0.03	<0.01	0.07	0.04	0.02	0.11	0.11	0.14
NH_3-N	mg/l	<0.01	<0.01	0.01	0.02	0.01	<0.01	0.03	0.03	0.01
Total-P	mg/l	0.006	0.015	0.012	0.005	0.015	0.017	<0.005	0.017	0.010
Ortho-P	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Table A-13

DILLON -- BLUE RIVER STUDY

Station: D-3 Dillon Reservoir Section D

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1445			1445			1445		
Depth	Meters	S			7			25		
Temp	Cent.	13.5			10.5			6.0		
pH	SU	8.4			7.7			7.35		
DO	mg/l	9.0			8.9			8.3		
Molybdenum	µg/l	425			355			465		
T. Iron	µg/l	80			120			-		
TKN	mg/l	0.30			0.30			0.20		
NO_3-N	mg/l	0.03			0.07			-		
NH_3-N	mg/l	<0.01			0.01			-		
Total-P	mg/l	0.008			0.008			0.009		
Ortho-P	mg/l	<0.005			<0.005			-		

Table A-14

DILLON -- BLUE RIVER STUDY

Station: E-1 Dillon Reservoir Section E

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1050			1050			1050		
Depth	Meters	S			8			35		
Temp	Cent.	13.6			9.9			-		
pH	SU	8.0			8.0			7.25		
DO	mg/l	8.9			8.8			8.3		
Molybdenum	ug/l	325			395			375		
T. Iron	ug/l	55			60			55		
TKN	mg/l	0.40			0.10			0.10		
NO_3-N	mg/l	0.31			0.08			0.12		
NH_3-N	mg/l	0.03			<0.01			0.03		
Total-P	mg/l	0.010			0.009			<0.005		
Ortho-P	mg/l	0.005			<0.005			0.015		

Table A-15

DILLON -- BLUE RIVER STUDY

Station: E-2 Dillon Reservoir Section E

Date	Mo/Day/Yr	06/29/73	07/10/73	08/16/73	06/29/73	07/10/73	08/16/73	06/29/73	07/10/73	08/16/73
Time	Mtly	1105	1400	1250	1105	1400	1250	1105	1400	1250
Depth	Meters	S	S	S	8	8	11	35	25	30
Temp	Cent.	13.3	16.8	15.5	9.5	9.2	8.5	-	6.2	5.8
pH	SU	7.8	8.3	7.2	7.45	7.7	7.2	7.45	7.5	7.4
DO	mg/l	8.9	6.9	7.9	8.7	7.2	7.7	8.2	7.2	7.1
Molybdenum	ug/l	315	270	230	325	230	320	330	375	500
T. Iron	ug/l	60	30	30	55	65	5	60	25	<5
TKN	mg/l	0.20	0.20	0.20	0.20	0.20	0.10	0.10	0.10	0.10
NO_3-N	mg/l	0.04	<0.01	0.02	0.06	0.04	0.07	0.11	0.10	0.14
NH_3-N	mg/l	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.02	0.03	0.01
Total-P	mg/l	0.007	0.012	0.012	0.006	0.017	0.011	<0.005	0.011	0.009
Ortho-P	mg/l	<0.005	<0.005	0.009	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Table A-16

DILLON -- BLUE RIVER STUDY

Station: E-3 Dillon Reservoir Section E

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1120			1120			1120		
Depth	Meters	S			8			35		
Temp	Cent.	13.5			9.6			-		
pH	SU	7.6			7.3			7.1		
DO	mg/l	8.9			8.8			8.1		
Molybdenum	µg/l	310			365			415		
T. Iron	µg/l	50			65			65		
TKN	mg/l	0.30			0.20			0.10		
NO_3-N	mg/l	0.03			0.05			0.11		
NH_3-N	mg/l	<0.01			<0.01			0.03		
Total-P	mg/l	0.007			0.008			0.005		
Ortho-P	mg/l	<0.005			<0.005			<0.005		

Table A-17

DILLON -- BLUE RIVER STUDY

Station: F-1 Dillon Reservoir Section F

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1145			1145			1145		
Depth	Meters	S			8			20		
Temp	Cent.	13.7			9.5			5.8		
pH	SU	7.8			7.7			7.25		
DO	mg/l	8.7			8.7			8.4		
Molybdenum	µg/l	305			345			375		
T. Iron	µg/l	60			55			40		
TKN	mg/l	0.20			0.20			0.20		
NO_3-N	mg/l	0.03			0.05			0.10		
NH_3-N	mg/l	<0.01			<0.01			0.02		
Total-P	mg/l	0.015			0.010			0.007		
Ortho-P	mg/l	<0.005			<0.005			<0.005		

Table A-18

DILLON -- BLUE RIVER STUDY

Station: F-2 Dillon Reservoir Section F

Date	Mo/Day/Yr	06/29/73	07/10/73	08/16/73	06/29/73	07/10/73	08/16/73	06/29/73	07/10/73	08/16/73
Time	Mtly	1155	1430	1230	1155	1430	1230	1155	1430	1230
Depth	Meters	S	S	S	8	8	9	24	24	15
Temp	Cent.	13.9	16.2	15.7	9.8	10.5	8.5	5.5	6.0	6.5
pH	SU	7.95	8.35	7.5	8.1	8.0	7.3	7.5	7.85	7.1
DO	mg/l	8.7	6.9	7.8	8.8	7.3	7.2	8.2	7.1	7.0
Molybdenum	µg/l	320	285	260	280	305	255	400	350	355
T. Iron	µg/l	60	25	25	80	40	25	50	20	<5
TKN	mg/l	0.30	0.20	0.30	0.30	0.10	<0.10	0.20	0.10	<0.10
NO_3-N	mg/l	0.03	0.02	<0.01	0.03	0.07	0.01	0.11	0.10	0.09
NH_3-N	mg/l	<0.01	<0.01	0.01	<0.01	0.02	<0.01	0.02	0.03	0.02
Total-P	mg/l	0.011	0.013	0.011	0.020	0.016	0.008	0.008	0.013	0.010
Ortho-P	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Table A-19

DILLON -- BLUE RIVER STUDY

Station: F-3 Dillon Reservoir Section F

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1210			1210					
Depth	Meters	S			7					
Temp	Cent.	15.0			11.1					
pH	SU	8.2			7.95					
DO	mg/l	8.8			8.8					
Molybdenum	µg/l	328			315					
T. Iron	µg/l	75			60					
TKN	mg/l	0.30			0.20					
NO_3-N	mg/l	0.03			0.05					
NH_3-N	mg/l	<0.01			<0.01					
Total-P	mg/l	0.011			0.009					
Ortho-P	mg/l	<0.005			<0.005					

Table A-20

DILLON -- BLUE RIVER STUDY

Station: G-1 Dillon Reservoir Section G

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1245			1245			1245		
Depth	Meters	S			7			35		
Temp	Cent.	13.3			10.6			-		
pH	SU	8.4			7.7			7.65		
DO	mg/1	8.8			8.7			8.4		
Molybdenum	µg/1	340			330			415		
Total Iron	µg/1	55			60			65		
TKN	mg/1	0.20			0.20			0.20		
NO_3-N	mg/1	0.04			0.05			0.10		
NH_3-N	mg/1	<0.01			<0.01			0.02		
Total-P	mg/1	0.023			0.136			0.008		
Ortho-P	mg/1	0.010			0.126			0.006		

Table A-21

DILLON -- BLUE RIVER STUDY

Station: G-2 Dillon Reservoir Section G

Date	Mo/Day/Yr	06/29/73	07/10/73	08/16/73	06/29/73	07/10/73	08/16/73	06/29/73	07/10/73	08/16/73
Time	Mtly	1255	1115	1700	1255	1115	1700	1255	1115	1700
Depth	Meters	S	S	S	7	7	10	35	35	30
Temp	Cent.	13.0	16.5	15.2	9.6	10.1	10.0	-	-	5.5
pH	SU	8.2	8.1	7.4	8.0	7.48	7.4	7.5	7.3	7.1
DO	mg/1	8.9	6.7	8.2	8.7	6.9	6.9	8.3	7.1	7.4
Molybdenum	µg/1	355	290	235	295	280	255	360	390	415
T. Iron	µg/1	55	35	15	55	45	20	40	20	<5
TKN	mg/1	0.10	0.10	<0.10	0.20	0.20	0.10	0.20	0.10	0.10
NO_3-N	mg/1	0.03	0.02	<0.01	0.08	0.04	0.02	0.11	0.10	0.14
NH_3-N	mg/1	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.02	0.03	<0.01
Total-P	mg/1	0.011	0.012	0.092	0.012	0.016	0.011	0.010	0.016	0.422
Ortho-P	mg/1	0.006	<0.005	0.086	0.007	<0.005	<0.005	0.007	<0.005	0.406

Table A-22

DILLON -- BLUE RIVER STUDY

Station: G-3 Dillon Reservoir Section G

Date	Mo/Day/Yr	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73	06/29/73	07/09/73	08/16/73
Time	Mtly	1310			1310			1310		
Depth	Meters	S			7			35		
Temp	Cent.	13.0			10.0			-		
pH	SU	8.3			8.15			7.45		
DO	mg/l	8.9			8.8			8.1		
Molybdenum	ug/l	330			345			435		
T. Iron	ug/l	75			75			45		
TKN	mg/l	0.20			0.30			0.20		
NO_3-N	mg/l	0.04			0.08			0.13		
NH_3-N	mg/l	<0.01			0.01			0.03		
Total-P	mg/l	0.144			0.012			0.013		
Ortho-P	mg/l	0.138			0.007			0.006		

Table A-23

DILLON -- BLUE RIVER STUDY

Station: BR-1	Blue River Downstream of Dam						
Date	Mo/Day/Yr	06/28/73	06/29/73	07/10/73	07/11/73	08/13/73	08/14/73
Time	Mtly	0730	1040	0740	1145	1355	1525
Flow	cfs	1460	1450	860	804	259	247
Temp.	Cent.	12	12	13	18	15	15
pH	SU	7.8	8.0	7.9	7.5	8.2	7.8
DO	mg/l	8.8	9.4	9.0	7.8	7.7	7.7
BOD_5	mg/l	2	<1	<1	<1	0.5	0.5
T Coli	T/100ml	18	<2	20	14	20	16
F Coli	T/100ml	<2	<2	2	2	8	<2
Molybdenum	µg/l	325	325	300	285	200	225
Total Iron	µg/l	65	65	80	30	32	10
TKN	mg/l	0.10	0.20	0.10	0.20	0.10	0.20
NO_3-N	mg/l	0.04	0.04	0.02	0.04	<0.01	<0.01
NH_3-N	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total-P	mg/l	0.007	0.005	0.006	0.009	0.010	0.008
Ortho-P	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sus. Solids	mg/l	6	8	1	2	1	1
Cl_2 Residual	mg/l						

Table A-24

DILLON -- BLUE RIVER STUDY

Station: BR-2 Blue River Before Confluence with Reservoir

Date	Mo/Day/Yr	06/27/73	06/28/73	07/09/73	07/11/73	08/14/73	08/15/73
Time	Mtly	1030	1230	1615	1315	1045	1030
Flow	cfs						
Temp.	Cent.	9	11	10	11	10	10
pH	SU	7.5	7.8	7.8	7.3	8.0	8.0
DO	mg/l	9.0	-	8.4	8.2	8.4	8.5
BOD_5	mg/l	2	-	<1	<1	0.3	0.3
T Coli	T/100ml	76	86	110	68	130	32
F Coli	T/100ml	4	10	22	4	2	5
Molybdenum	µg/l	<10	<10	<10	<10	<10	<10
T. Iron	µg/l	565	605	170	160	120	145
TKN	mg/l	0.22	0.20	0.20	0.20	0.10	<0.10
NO_3-N	mg/l	0.08	0.09	0.07	0.06	0.13	0.15
NH_3-N	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Total-P	mg/l	0.028	0.047	0.015	0.024	0.014	0.019
Ortho-P	mg/l	0.009	0.012	0.010	0.010	<0.005	0.012
Sus. Solids	mg/l	-	-	4	4	1	1
Cl_2 Residual	mg/l						

Table A-25

DILLON -- BLUE RIVER STUDY

Station: BR-3 Blue River Upstream

Date	Mo/Day/Yr	06/27/73	06/28/73	07/09/73	07/11/73	08/14/73	08/15/73
Time	Mtly	1225	1345	1525	1415	1220	1135
Flow	cfs	17.5	17.5	0.6	0.45	0.17	0.17
Temp.	Cent.	8	8	12	12	8.5	8
pH	SU	7.4	8.2	7.9	7.7	7.8	7.8
DO	mg/l	8.5	8.8	7.6	7.2	7.9	8.0
BOD_5	mg/l	5	-	<1	<1	0.3	<0.1
T Coli	T/100ml	14	6	90	2	28	6
F Coli	T/100ml	6	4	4	<2	<2	<2
Molybdenum	µg/l	<10	<10	<10	<10	<10	<10
T. Iron	µg/l	150	135	65	30	5	<5
TKN	mg/l	0.13	0.20	0.10	0.10	0.10	<0.10
NO_3-N	mg/l	0.10	0.10	0.01	0.02	<0.01	0.03
NH_3-N	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total-P	mg/l	0.012	0.007	<0.005	<0.005	0.005	0.007
Ortho-P	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sus. Solids	mg/l	-	-	<1	<1	<1	<1
Cl_2 Residual	mg/l						

Table A-26

DILLON -- BLUE RIVER STUDY

Station: SR-1 Snake River Before Confluence with Reservoir

Date	Mo/Day/Yr	06/28/73	06/29/73	07/10/73	07/11/73	08/13/73	08/14/73
Time	Mtly	1020	1100	1015	0940	1310	1440
Flow	cfs	305	296	160	150	57	56
Temp.	Cent.	7	7	8	8	11	15
pH	SU	7.2	8.1	7.1	7.3	7.9	7.5
DO	mg/l	10.4	9.4	9.3	8.7	8.0	7.5
BOD_5	mg/l	-	1	<1	<1	1.0	0.1
T Coli	T/100ml	20	8	20	38	210	14
F Coli	T/100ml	2	4	4	4	70	<2
Molybdenum	µg/l	<10	<10	<10	<10	<10	<10
T. Iron	µg/l	430	290	185	185	262	275
TKN	mg/l	0.20	0.10	<0.10	0.10	0.20	0.30
NO_3-N	mg/l	0.08	0.07	0.07	0.07	0.05	0.04
NH_3-N	mg/l	<0.01	<0.01	<0.01	<0.01	0.03	0.02
Total-P	mg/l	0.010	0.010	0.005	<0.005	0.015	0.013
Ortho-P	mg/l	<0.005	0.005	<0.005	<0.005	<0.005	<0.005
Sus. Solids	mg/l	-	7	3	2	5	3
Cl_2 Residual	mg/l						

Table A-27

DILLON -- BLUE RIVER STUDY

Station: SR-2 Snake River Upstream

Date	Mo/Day/Yr	06/28/73	06/29/73	07/10/73	07/11/73	08/13/73	08/14/73
Time	Mtly	1145	1230	1045	1025	1130	1355
Flow	cfs	-	-	116	130	51	31
Temp.	Cent.	8	9	7	7	7	12
pH	SU	7.9	7.8	7.2	6.5	7.5	7.0
DO	mg/l	10.5	8.4	8.9	8.5	8.6	7.7
BOD_5	mg/l	-	<1	<1	<1	0.4	0.2
T Coli	T/100ml	4	<2	4	10	8300	32
F Coli	T/100ml	<2	<2	<2	<2	7200	<2
Molybdenum	µg/l	<10	<10	<10	<10	<10	<10
T. Iron	µg/l	300	485	195	195	275	275
TKN	mg/l	0.10	<0.10	<0.10	<0.10	<0.10	<0.1
NO_3-N	mg/l	0.10	0.08	0.08	0.08	0.07	0.05
NH_3-N	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total-P	mg/l	0.009	0.007	<0.005	0.005	0.007	0.009
Ortho-P	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sus. Solids	mg/l	-	5	4	3	4	2
Cl_2 Residual	mg/l						

Table A-28

DILLON -- BLUE RIVER STUDY

Station: TM-1 Ten Mile Creek Before Confluence with Reservoir

Date	Mo/Day/Yr	06/27/73	06/29/73	07/09/73	07/10/73	08/14/73	08/15/73
Time	Mtly	1735	1000	1135	1220	0855	0850
Flow	cfs	636	546	296	254	54	52
Temp.	Cent.	11.5	5.5	10	10	8	7
pH	SU	7.8	7.6	7.1	7.1	7.8	7.8
DO	mg/l	8.2	9.5	9.0	9.0	8.9	8.6
BOD_5	mg/l	<1	2	<1	<1	0.2	0.4
T Coli	T/100ml	20	4	190	16	180	46
F Coli	T/100ml	2	2	20	2	2	4
Molybdenum	µg/l	70	80	75	90	145	140
T. Iron	µg/l	790	210	100	155	150	125
TKN	mg/l	0.30	0.10	0.20	0.10	<0.10	<0.10
NO_3-N	mg/l	0.06	0.07	0.06	0.06	0.06	0.09
NH_3-N	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total-P	mg/l	0.028	0.005	-	<0.005	0.007	0.009
Ortho-P	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sus. Solids	mg/l	32	5	3	4	1	<1
Cl_2 Residual	mg/l						

Table A-29

DILLON -- BLUE RIVER STUDY

Station: TM-2	Tenmile Creek Upstream						
Date	Mo/Day/Yr	06/27/73	06/29/73	07/09/73	07/10/73	08/14/73	08/15/73
Time	Mtly	1525	0735	1250	1415	0735	0725
Flow	cfs	131		71			
Temp.	Cent.	11	3	10	13	6	4
pH	SU	7.6	8.1	7.7	7.3	7.5	7.2
DO	mg/l	8.9	6.0	8.3	7.9	8.7	8.8
BOD_5	mg/l	<1	1	<1	<1	0.3	0.1
T Coli	T/100ml	6	6	18	8	36	32
F Coli	T/100ml	2	<2	2	4	2	4
Molybdenum	µg/l	80	75	80	45	105	125
T Iron	µg/l	1440	365	185	155	190	1500
TKN	mg/l	0.40	0.10	0.10	0.10	<0.10	0.10
NO_3-N	mg/l	0.07	0.08	0.06	0.05	0.06	0.06
NH_3-N	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total-P	mg/l	0.060	0.010	0.008	<0.005	0.007	0.041
Ortho-P	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	0.006
Sus. Solids	mg/l	42	5	2	2	3	28
Cl_2 Residual	mg/l						

Table A-30

DILLON -- BLUE RIVER STUDY

Station: STP-F Frisco Sewage Treatment Plant Effluent

Date	Day/Yr	06/27/73	06/28/73	07/09/73	07/10/73	08/13/73	08/15/73
Time	Mtly	1630	1640	1045	1240	1525	0945
Flow	cfs	.12	.12	0.16	0.18	0.11	0.20
Temp.	Cent.	18	18.5	16	18	18	15
pH	SU	9.4	9.2	8.4	8.5	7.5	7.2
DO	mg/l	18.7	11.2	11.7	>15	1.2/1.5	1.4
BOD_5	mg/l	61	48	37	7	7.5	9.9
T Coli	T/100ml	13000	46000	6500	17000	76000	48000
F Coli	T/100ml	100	180	220	1100	200	50
Molybdenum	ug/l	225	220	145	165	165	170
T. Iron	ug/l	305	360	200	180	317	315
TKN	mg/l	23.2*	16.8*	14.1*	13.6*	23.2	23.7
NO_3-N	mg/l	0.43	0.44	0.37	0.39	0.06	0.02
NH_3-N	mg/l	6.70*	6.20*	5.55	4.80	16.3	16.7
Total-P	mg/l	8.00*	8.20*	6.55	5.75*	9.22	9.28
Ortho-P	mg/l	6.80	6.30	6.20	4.65	5.74	7.34
Sus. Solids	mg/l	80	76	52	56	20	7
Cl_2 Residual	mg/l	-	-	1.0	0.75	0.5	0.15

* Held beyond recommended storage time before processing.

Table A-31

DILLON -- BLUE RIVER STUDY

STATION: STP-B Breckenridge Sewage Treatment Plant Effluent

Date	Mo/Day/Yr	06/27/73	06/28/73	07/09/73	07/11/73	08/14/73	08/15/73
Time	Mtly	1110	1300	1450	1335	1115	1055
Flow	cfs	1.46	1.36	1.04	1.06	1.09	1.15
Temp.	Cent.	9.5	10.5	13	12	11	11.5
pH	SU	7.4	7.6	6.9	6.8	7.3	7.2
DO	mg/l	7.7	8.2	6.3	5.8	5.3	-
BOD_5	mg/l	53	53	>25	35	15.5	8.4
T Coli	T/100ml	4,600,000	5000	810,000	450,000	180,000	4300
F Coli	T/100ml	4000	100	220,000	50,000	130,000	300
Molybdenum	µg/l	<10	<10	<10	<10	<10	<10
T. Iron	µg/l	935	525	275	265	120	100
TKN	mg/l	12.1*	11.3*	11.2*	12.7*	22.9	12.7
NO_3-N	mg/l	0.16	0.20	0.01	<0.01	0.01	<0.01
NH_3-N	mg/l	4.20*	3.45*	7.70	9.75	14.2	9.55
Total-P	mg/l	7.95*	4.15*	3.40	4.95	4.53	3.72
Ortho-P	mg/l	1.90	1.90	2.45	3.45	3.59	3.02
Sus. Solids	mg/l	-	66	23	26	12	9
Cl_2 Residual	mg/l	-	0.0	0.0	0.0	0.0	0.15

* Held beyond recommended storage time before processing.

Table A-32

DILLON -- BLUE RIVER STUDY

Station: STP-ED East Dillon (Summit Cove) Sewage Treatment Plant Effluent

Date	Mo/Day/Yr	06/28/73	06/29/73	07/10/73	07/11/73	08/13/73	08/14/73	08/15/73
Time	Mtly	1000	1150	1030	0955	1255	1320	1215
Flow	cfs	0.01	0.02		0.001		0.17	
Temp.	Cent.	15.5	15		15		15	
pH	SU	7.8	7.7		6.9		7.5	
DO	mg/l	7.1	6.0		6.1		4.5	
BOD_5	mg/l	-	<3		2		2.6	
T Coli	T/100ml	<2	6		<2		23,000	
F Coli	T/100ml	<2	4		<2		19,000	
Molybdenum	µg/l	<10			<10		<10	
T. Iron	µg/l	140	120	NO FLOW	670	NO FLOW	15	NO FLOW
TKN	mg/l	21.2*	20.8*		26.2*		29.2	
NO_3-N	mg/l	0.37	0.41		0.14		0.09	
NH_3-N	mg/l	14.4*	20.7*		25.0		28.0	
Total-P	mg/l	0.060*	0.040*		0.035		0.093	
Ortho-P	mg/l	0.010	0.010		0.010		<0.005	
Sus. Solids	mg/l	-	5		16		3	
Cl_2 Residual	mg/l	-	0.5		Trace		0.0	

* Held beyond recommended storage time before processing.

Table A-33

DILLON -- BLUE RIVER STUDY

Station: STP-S Summit Co. #1 Sewage Treatment Plant Effluent

Date	Mo/Day/Yr	06/27/73	06/28/73	07/10/73	07/11/73	08/13/73	08/14/73	08/15/73
Time	Mtly	1705	1610	0805	1220	1450	1530	0830
Flow	cfs	0.16	0.15	.09	.12	0.07		0.22
Temp.	Cent.	14	13	12	16	15		14
pH	SU	6.7	6.6	6.6	6.9	7.0		7.0
DO	mg/l	3.4	7.0	3.0	2.8	6.7		4.6
BOD_5	mg/l	25	25	9	30	0.5		9.6
T Coli	T/100ml	290,000	360,000	80,000	1,200,000	<10	NO FLOW	730,000
F Coli	T/100ml	22,000	2500	600	28,000	<10		22,000
Molybdenum	µg/l	<10	<10	<10	50	<10		10
T. Iron	µg/l	495	325	265	615	77		130
TKN	mg/l	5.58*	5.19*	15.2*	15.6*	3.2		6.3
NO_3-N	mg/l	<0.01	0.02	<0.01	<0.01	0.35		0.21
NH_3-N	mg/l	2.60*	2.05*	12.6	10.1	1.70		4.60
Total-P	mg/l	5.35*	1.40*	1.32	3.90	0.305		0.550
Ortho-P	mg/l	4.70	0.70	1.25	3.90	0.177		0.298
Sus. Solids	mg/l	44	40	17	50	5		6
Cl_2 Residual	mg/l	-	-	0.0	0.0	0.5		0.0

* Held beyond recommended storage time before processing.

Table A-34

DILLON -- BLUE RIVER STUDY

Station: STP-CM Copper Mountain Sewage Treatment Plant Effluent

Date	Mo/Day/Yr	06/28/73	06/29/73	07/09/73	07/10/73	08/14/73	08/15/73
Time	Mtly	1615	0815	1355	1340	0820	0800
Flow	cfs		0.09	0.03	0.04	0.07	0.06
Temp.	Cent.		8.5	13	13	11	10
pH	SU		8.0	7.1	7.2	6.8	5.4
DO	mg/l		6.8	6.8	7.1	7.4	7.7
BOD_5	mg/l		5	<1	Sterile	1.1	1.6
T Coli	T/100ml		17,000	30	30	4000	<2
F Coli	T/100ml	NO FLOW	8900	10	20	40	<2
Molybdenum	µg/l		380	115	105	<10	<10
T. Iron	µg/l		75	65	35	25	15
TKN	mg/l		1.81*	1.7*	0.7*	0.50	0.65
NO_3-N	mg/l		3.2*	5.5	5.8	4.5	5.1
NH_3-N	mg/l		0.90*	0.80	0.70	0.65	0.55
Total-P	mg/l		0.340*	0.030	0.020	0.031	0.040
Ortho-P	mg/l		0.080	0.020	0.020	0.008	0.010
Sus. Solids	mg/l		4	<1	<1	<1	2
Cl_2 Residual	mg/l		-	0.25	0.2	0.5	0.5

* Held beyond recommended storage time before processing.

Table A-35

DILLON -- BLUE RIVER STUDY

Station: STP-D Dillon Sewage Treatment Plant Effluent

Date	Mo/Day/Yr	06/28/73	06/29/73	07/10/73	07/11/73	08/13/73	08/14/73
Time	Mtly			1150	1125	1340	1515
Flow	cfs			0.06	0.06		
Temp.	Cent.			18	22		
pH	SU			8.8	8.1		
DO	mg/1			7.9	7.1		
BOD_5	mg/1			24	29		
T Coli	T/100ml	OUTFALL SUBMERGED	OUTFALL SUBMERGED	34,000	37,000	NO FLOW	NO FLOW
F Coli	T/100ml			2800	2000		
Molybdenum	µg/1			<10	<10		
T. Iron	µg/1			280	285		
TKN	mg/1			7.7*	9.2*		
NO_3-N	mg/1			0.08	0.05		
NH_3-N	mg/1			1.15	0.15		
Total-P	mg/1			4.85*	5.40		
Ortho-P	mg/1			3.30	3.30		
Sus. Solids	mg/1			104	72		
Cl_2 Residual	mg/1			0.5	0.25		

* Held beyond recommended storage time before processing.

APPENDIX B

DILLON RESERVOIR CROSS - SECTIONS

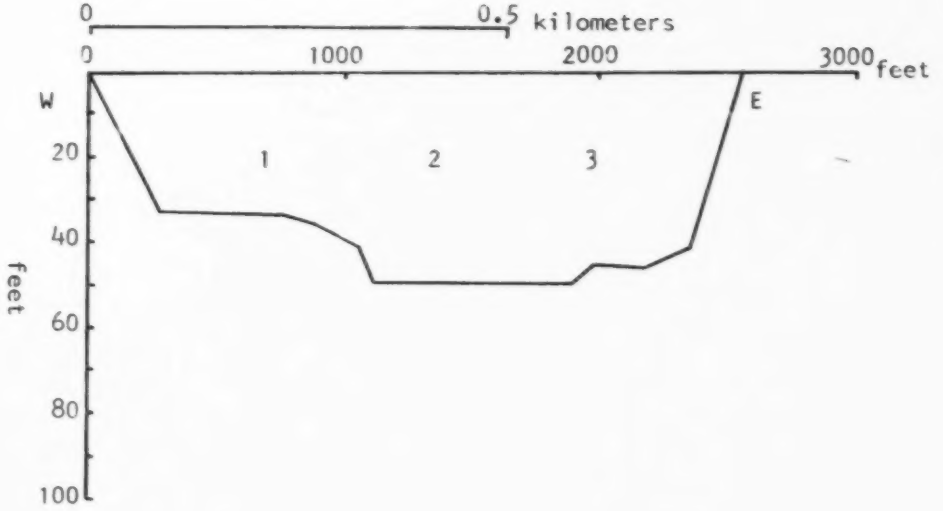


Figure 1. Section A-A. Blue River Arm at Silver Dollar Island.

Figure 2. Section B-B. Section at outlet of Blue River Arm.

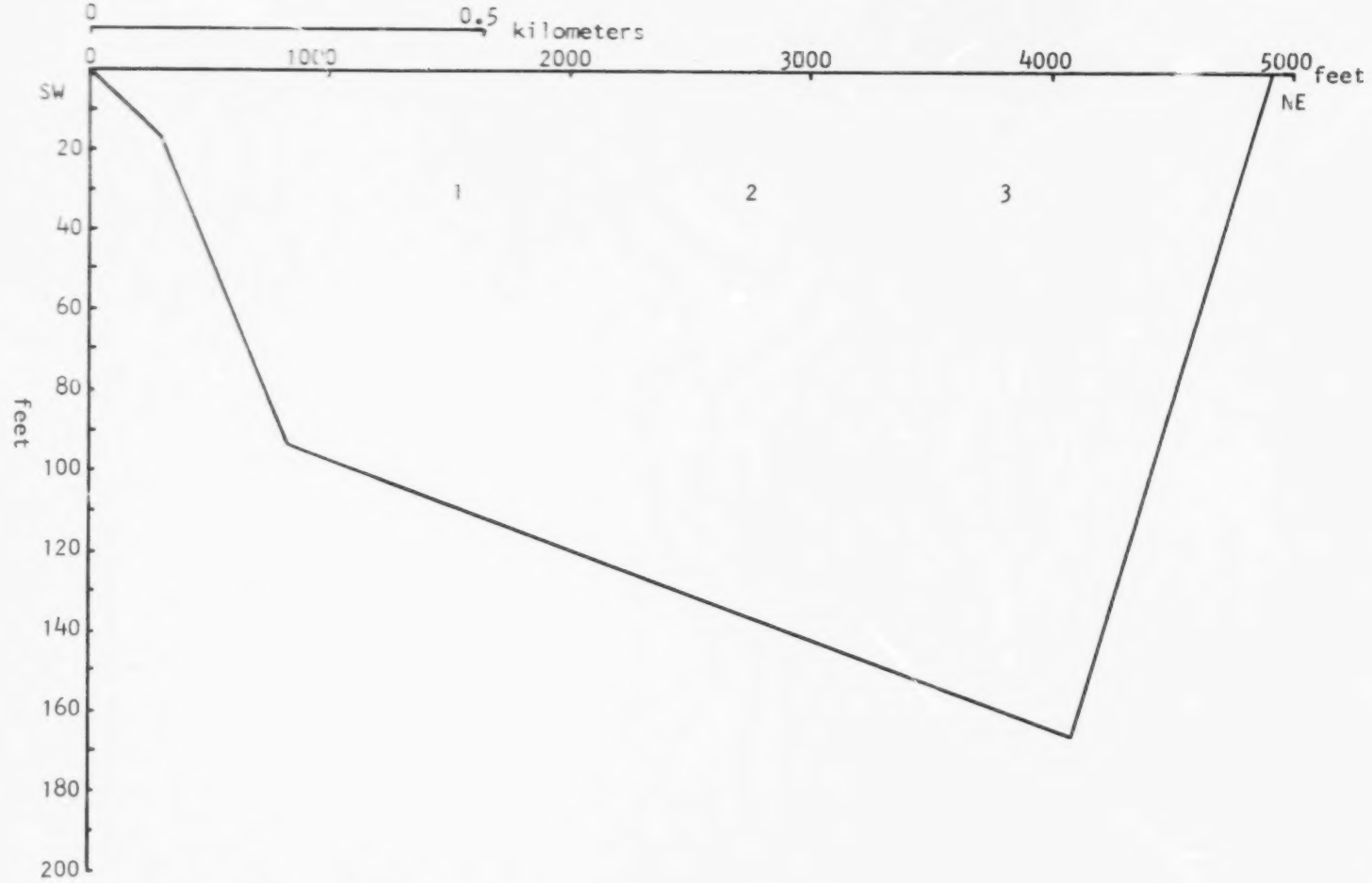


Figure 3. Section C-C. Section of Frisco Bay - Ten Mile Creek Arm.

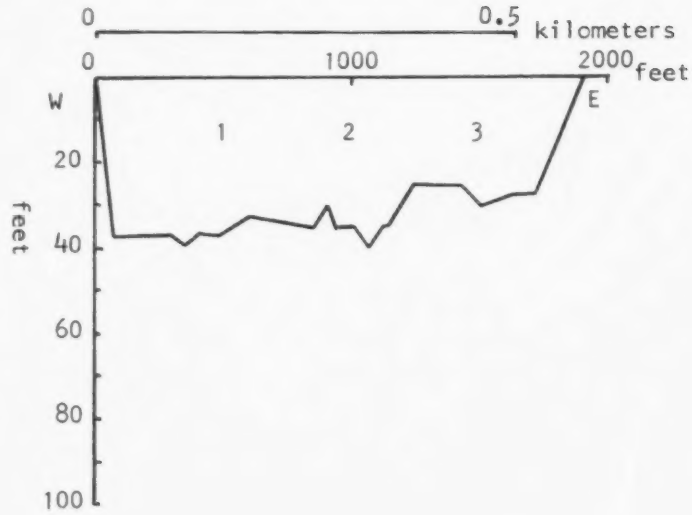


Figure 4. Section D-D. Section at outlet of Ten Mile Creek Arm.

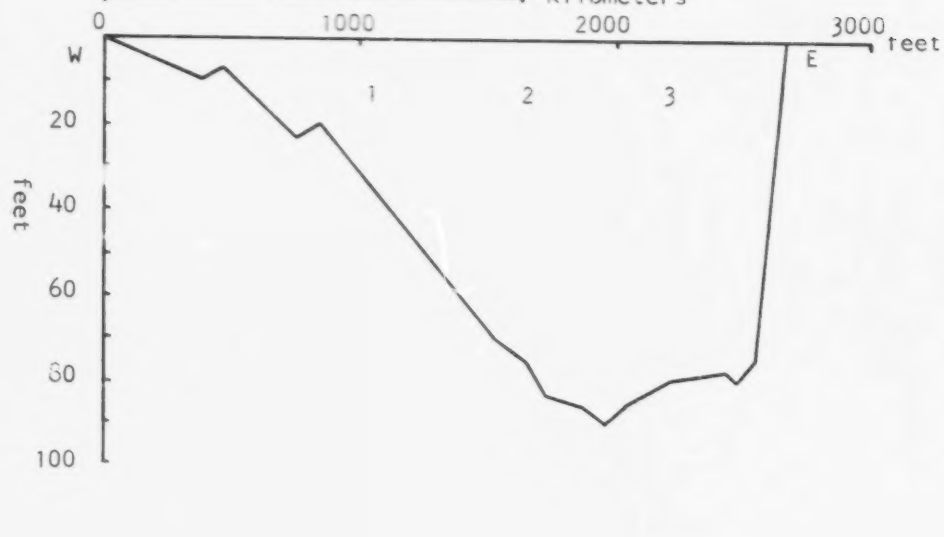


Figure 5. Section E-E. Section at outlet of Snake River Arm.

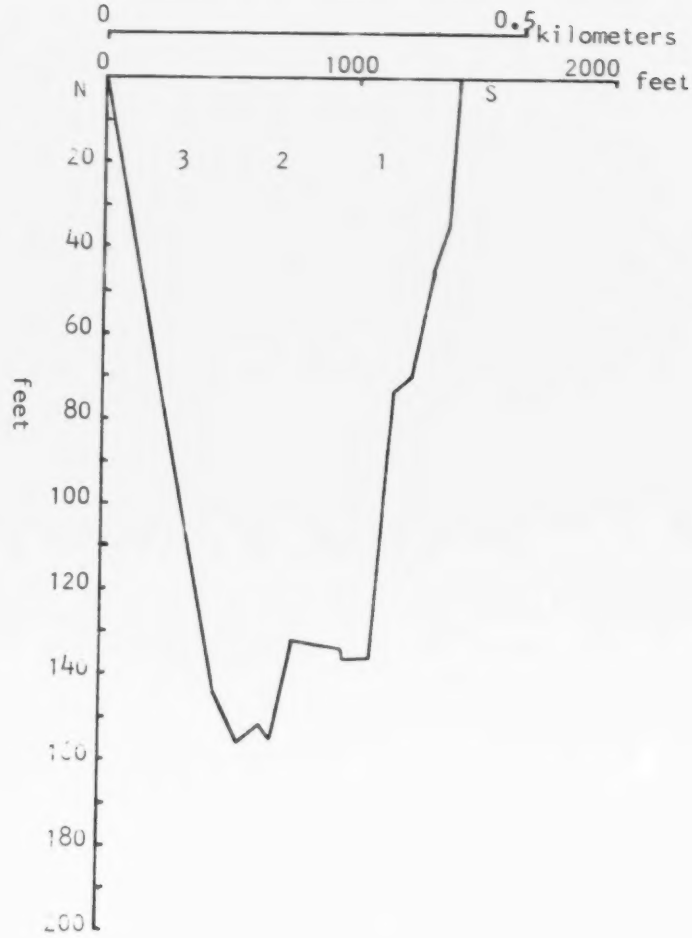


Figure 6. Section F-F. Section at outlet of Dillon Bay.

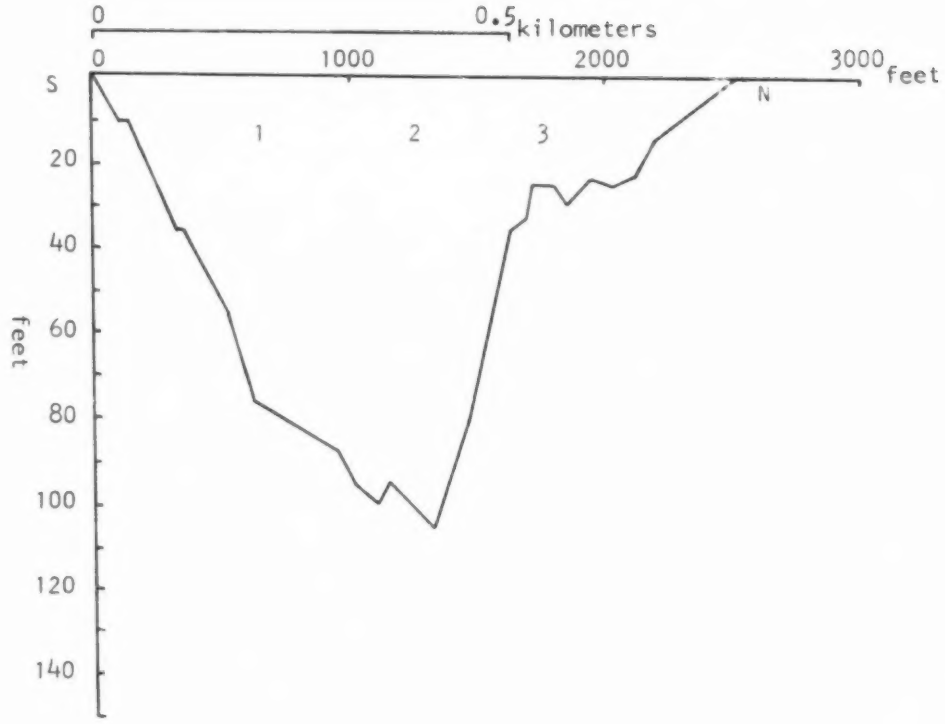
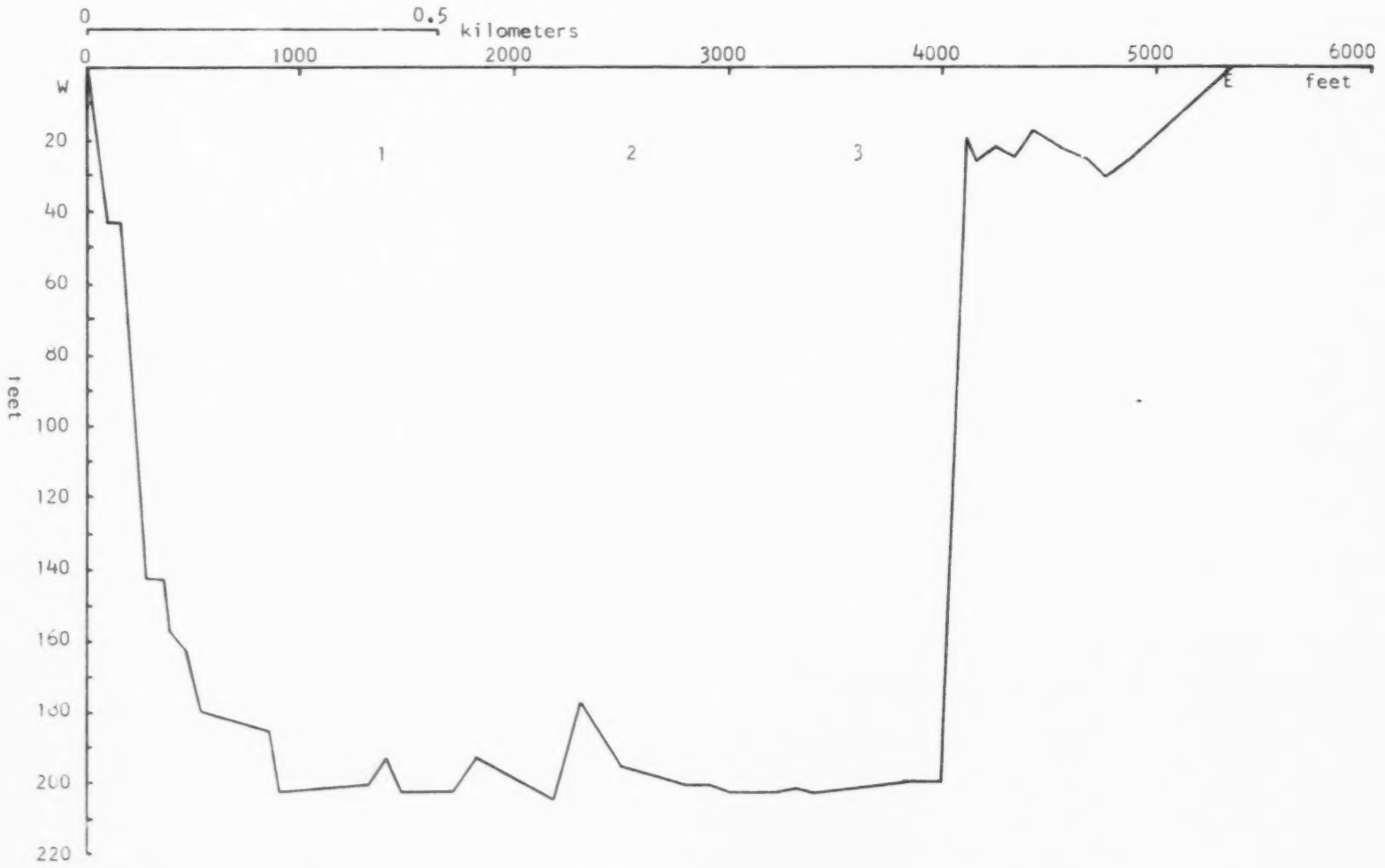


Figure 7. Section G-G. Section thru main reservoir - Overlook to West Portal.



APPENDIX C

REFERENCES

LITERATURE CITED

Environmental Protection Agency, National Eutrophication Research Program. 1971. Algal Assay Procedure, Bottle Test. EPA. Corvallis. 82 pp.

Environmental Protection Agency, Region VIII, Air and Water Programs Division and Colorado Department of Health, Water Pollution Control Division. 1972. Report on Water Quality Management Analysis of Summit County, Colorado. EPA. Denver. 129 pp.

Li, Jerome, C.R. 1959. Introduction to Statistical Interference. Edwards Brothers, Inc. Ann Arbor. 553 pp.

Strickland, J.D.H. and T.R. Parsons. 1968. Fluorometric Determination of Chlorophylls. A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada. Bull. 167: 201-202

Chappell, W.R. 1973. Transport and the Biological Effects of Molybdenum in the Environment. Presented at Heavy Metals in the Aquatic Environment Conference, Vanderbilt University, Nashville, Tennessee, 45 pp.

Environmental Protection Agency. 1973. Proposed Criteria For Water Quality - Volume I. EPA. Washington, D.C., 425 pp.

Mackenthun, K.M. 1969. The Practice of Water Pollution Biology. U.S. Dept. of the Interior, Fed. Water Poll. Control Administration, 281 pp.

Mackenthun, K.M. 1965. Nitrogen and Phosphorus in Water. An Annotated Selected Bibliography of Their Biological Effects. U.S. Dept. of Health, Education, and Welfare, Public Health Service, 111 pp.